THE

HUNDRED GREATEST MEN

PORTRAITS

OF THE

ONE HUNDRED GREATEST MEN OF HISTORY

REPRODUCED FROM FINE AND RARE ENGRAVINGS

VOLUME VI

Science

MATHEMATICIANS, PHYSICIANS, NATURALISTS

WITH AN INTRODUCTION

BY PROFESSOR H. HELMHOLTZ

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INTRODUCTION TO VOLUME VI.

By Professor HELMHOLTZ.

Es ist sehr lehrreich sich in den Gedankenkreis und die Sinnesweise alter Zeiten zurückzuversetzen; aber man stösst dabei auf unerwartete Schwierigkeiten. Vieles, was wir von unserer ersten Kindheit an gewusst und gekonnt haben, ohne dass unserer Erinnerung nach es uns jemand gelehrt hätte, was uns daher als ganz einfach und selbstverständlich erscheint, das haben, wie wir staunend entdecken, in alten Zeiten auch die leitenden Männer der intelligentesten Nationen nicht gekonnt und nicht gewusst. Gerade bei solcher Gelegenheit tritt am entschiedensten hervor, dass wir der Arbeit der vorausgegangenen Generationen noch viel mehr verdanken, als wir uns gewöhnlich klar machen.

Solche Gedanken drängen sich uns auf, wenn wir auf die Geschichte der Naturwissenschaften zurückblicken. Nichts ist einfacher, als die Methode der Forschung dieser Wissenschaften, wie sich dieselbe schliesslich, nachdem viele Irrwege vergebens betreten waren, festgestellt hat. Diese Methode, die unter dem Namen der *inductiven* beschrieben zu werden pflegt, ist in der That nichts anderes als das Verfahren, welches der sogenannte gesunde Menschenverstand für die praktischen Zwecke des täglichen Lebens ohne alle wissenschaftliche Schulung von selbst einzuschlagen pflegt, und von dessen Anwendung wir selbst bei den intelligenteren Thieren unverkennbare Spuren finden. Durch Erfahrung suchen wir kennen zu lernen, wie sich die uns umgebenden Dinge unter diesen oder jenen Umständen, namentlich auch bei den Eingriffen, die wir durch unsre Handlungen machen, zu verhalten pflegen. Wir setzen dann voraus, dass in jedem neu eintretenden Falle der Verlauf der Dinge der gleiche sein werde, wie in allen früheren Fällen von hinlänglich ähnlicher Art.

Der Unterschied zwischen der wissenschaftlichen Forschung und der alltäglichen Erfahrung liegt nur darin, dass wir in letzterer die Fälle so hinnehmen, wie sie der Zufall uns vorführt, dass wir uns mit den allmälig sich verdunkelnden Erinnerungen des Gesehenen begnügen, wie sie in unserm Gedächtnisse haften bleiben, und dass das einzige Maass, nach welchem wir quantitative und qualitative Unterschiede beurtheilen, meist nur durch die Intensität und Art der sinnlichen Empfindung gegeben ist. Bei wissenschaftlicher Forschung dagegen suchen wir möglichst grosse Vollständigkeit in der Beobachtung der einzelnen Fälle und ihrer Abänderungen zu erreichen, indem wir sie entweder aufsuchen, wo sie sich von selbst darbieten, oder sie absichtlich durch den Versuch herbeiführen. Namentlich suchen wir scharf und bestimmt die Bedingungen abzugrenzen, von denen es abhängt, ob ein gewisser Erfolg eintritt oder ausbleibt, beziehlich in welcher Grösse er eintritt, und ruhen nicht eher, als bis wir in jedem einzelnen neu eintretenden Falle ähnlicher Art vorauszusagen wissen, was geschehen wird. Indem wir das Gefundene in genau definirte Begriffe fassen, in Wort und Schrift fixiren, erweitern wir die Erfahrung jedes Einzelnen durch die Erfahrung aller Mitlebenden und Vorausgegangenen. Wir sind dabei sicher, dass jede Abweichung von einem für wahr gehaltenen Gesetz die allgemeine Aufmerksamkeit um so stärker erregen wird, je fester der Glauben an seine Richtigkeit war. So bleiben die schon gewonnenen Ergebnisse der Wissenschaft einer dauernden Controlle ihrer Wahrheit oder eventueller Verbesserung unterworfen. Aber alles dies ist im Grunde nichts als eine möglichst sorgfältige und consequente Ausführung dessen, was ein verständiger Mann für die nächstliegenden praktischen Zwecke auch ohne alle wissenschaftliche Schulung zu thun pflegt.

Natürlich dürfen wir uns nicht darüber wundern, wenn dem Jünger der Wissenschaft eine um so schwerere Arbeit des Denkens zugemuthet wird, je umfassender und je schärfer bestimmt die Gesetze werden, welche er verstehen und anwenden soll. Die allgemeinsten Principien der Mechanik in ihrer abstract mathematischen Fassung scheinen freilich von der Anschaulichkeit eines populären Erfahrungssatzes weit entfernt zu sein. Sie sind die Zauberformeln geworden, mit deren Hilfe die moderne Menschheit die widerstrebenden Gewalten der Natur in ihren Dienst gebannt hat, und doch sind sie auf demselben Wege gewonnen, der mit kleinen Fertigkeiten und Kunstgriffen des häuslichen Lebens und des Handwerks begonnen hat.

Dass die Nationen des classischen Alterthums weniger naturwissenschaftliche Kenntnisse gehabt haben, als wir, die wir auf ihren Schultern stehen, wird uns nicht in Erstaunen setzen dürfen. Wir wundern uns vielleicht öfter darüber, dass sie dieses und jenes gewusst haben, als über das Gegentheil. Was uns aber immer wieder in Verwunderung setzt, ist, dass diese Völker, die in der Ausbildung der Sprache, des Rechtes und der staatlichen Ordnung, in der Geschichtschreibung und philosophischen Abstraction uns in keiner Weise nachstanden, in vielen Richtungen künstlerischer Thätigkeit uns sogar entschieden überlegen waren, eine auffallende Unfähigkeit zeigen die richtigen Wege für die Lösung naturwissenschaftlicher Probleme zu finden, ja auch nur die richtigen Fragen zu stellen. Es macht den Eindruck, als sei ihnen die Methode, welche schliesslich die reichen Früchte gezeitigt hat, zu einfach und zu einfältig erschienen, um Grosses von ihr zu hoffen, und dass sie geglaubt haben erheblichere Resultate nur durch stärkere Anspannung tiefsinnigen Denkens erreichen zu können.

Dass ihnen die Fähigkeit, die ich vorher als gesunden Menschenverstand ohne wissenschaftliche Schulung bezeichnete, auch in der Beobachtung der Aussenwelt nicht gefehlt habe, brauche ich nicht hervorzuheben. Sie ist ausserdem dem künstlerischen Talent und der Fähigkeit, charakteristische Typen künstlerisch darzustellen, nahe verwandt. Denn ein solcher Typus ist auch die Erscheinungsweise eines gesetzlichen Verhaltens. Wir finden geradezu ein hervorragendes Beispiel einer solchen mehr künstlerischen als wissenschaftlichen Begabung in *Hippokrates.* Er hat die Regelmässigkeiten im Ablauf und in der Verbreitung der Krankheiten aufzufinden und zu beschreiben gewusst und so die erste Ordnung in diesem Gebiete geschaffen, in welchem unverkennbar die Sonderung der verschiedenen zusammenwirkenden Ursachen am aller schwierigsten ist. Wissenschaftliche Schulung fehlte ihm nicht ganz. Eine ziemliche Anzahl guter medicinischer Kenntnisse scheint in der Schule der Asklepiaden, aus der er hervorging, überliefert worden zu sein, und er kannte, was seine Zeit an wissenschaftlichen Theorien hervorgebracht hatte. Diese waren aber freilich der Art, dass man urtheilen muss, *Hippokrates* sei troz seiner theoretischen Bildung, nicht durch dieselbe ein grosser Arzt geworden. Er bezieht sich auf seine Theorien eben immer nur da, wo sich ihre Folgerungen den Thatsachen gutwillig anpassen; wo nicht, übergeht er sie mit Stillschweigen. Seine Schüler und Nachfolger aber, denen die Hauptsache, nämlich sein ausgezeichnetes Beobachtungstalent

fehlte, suchten seine Grösse gerade in dem, wo er schwach war, nämlich in den Theorien, und zogen aus diesen deductiv Schlüsse, die sie nicht etwa an den Thatsachen prüfen zu müssen meinten, sondern die sie statt der Thatsachen festhielten. Dasselbe Verhältniss wiederholte sich immer wieder, so oft ein grosser Meister der Beobachtung aufgetreten war, und kann als das charakteristische Zeichen einer Entwicklungsstufe der Wissenschaft angesehen werden, wo diese noch nicht zum Bewusstsein der richtigen Principien ihrer Methode gekommen ist.

Allerdings haben die Griechen auch zur Auffindung dieser Principien die ersten Schritte gethan. Dass es darauf ankomme in den Beobachtungswissenschaften zunächst einen möglichst vollständigen Überblick der Thatsachen zu gewinnen und die Erfahrungen der Generationen zu sammeln, hat *Aristoteles* richtig erkannt und sich selbst an das Werk gemacht, um dies für die naturhistorischen, zum Theil auch für die physikalischen Wissenschaften zu leisten, *Galenus* später für die medicinischen, beide mit grosser Einsicht und richtigem Urtheil. Daneben haben *Sokrates* und *Aristoteles* auch richtige Anfänge der Erkenntnisstheorie entwickelt, ersterer indem er die wissenschaftliche Wichtigkeit der Bildung von scharf definirten Begriffen an Beispielen erläuterte, letztrer indem er die logischen Principien der deductiven Methode, die Entwickelung der Folgerungen aus gegebenen Vordersätzen, entwickelte. Was beide in dieser Beziehung geleistet haben, machte grossen Eindruck auf ihre Zeitgenossen und erregte überschwängliche Hoffnungen. Für uns ist es kaum noch möglich uns in einen Zustand der geistigen Bildung zurückzudenken, wo die Sätze der gewöhnlichen Logik als neue und überraschende Einsichten erscheinen, und doch mag keine geringe Kraft der Abstraction dazu gehört haben, sie das erste Mal klar in Worte zu fassen.

Die deductive Methode findet ihre berechtigte Anwendung aber erst dann, wenn richtige und hinreichend allgemeine Vordersätze gewonnen worden sind, aus denen Folgerungen für besondere Fälle hergeleitet werden können. Dies war dem Alterthum nur in einem Gebiete, dem der Geometrie, gelungen, welche, wie es scheint, zuerst von den Aegyptern für praktische Zwecke ausgearbeitet, von *Pythagoras* den Griechen überliefert und von *Eukleides* in eine schon sehr vollendete wissenschaftliche Form gebracht wurde. Dass auch die Axiome der Geometrie, diese allgemeinen Vordersätze, aus denen alle andern Sätze dieser Wissenschaft abgeleitet werden

können, aus der Erfahrung und nicht aus der Natur des reinen Denkens abgeleitet sind, habe ich an andrem Orte zu beweisen gesucht.

Uebrigens waren auch einige physikalische Gesetze im engeren Sinne schon dem Alterthum bekannt. *Pythagoras* kannte die einfachen Verhältnisse der Länge von Saiten, welche den consonanten musikalischen Intervallen entsprechen. *Archimedes* kannte die Gesetze der Zurückwerfung des Lichts, und viele Gesetze der Statik, z. B. die für das Gleichgewicht des Hebels und für das der in Flüssigkeiten eingetauchten schweren Körper. Er begründete darauf die noch jetzt gebrauchten Methoden, das specifische Gewicht der Körper zu finden. *Hero* kannte die Wirkungen des Luftdrucks, *Claudius Ptolemaeus* die Gesetze der Strahlenbrechung in der Atmosphäre.

Namentlich aber in der Astronomie hatte man schon früh eine ziemlich genaue Kenntniss von der Weise, wie Sonne, Mond, Planeten und Fixsterne sich am Himmel scheinbar bewegen. Auch hier waren Aegypter und Babylonier den Griechen vorangegangen. Der Calender für die bürgerliche Zeitrechnung wurde allmälig immer mehr verbessert und genauer mit den Bewegungen von Sonne und Mond in Einklang gesetzt. Die astronomischen Forschungen waren sehr geeignet durch die Anschauung der genauen und unabänderlichen Gesetzmässigkeit in so grossen Verhältnissen den menschlichen Geist zum Aufsuchen einer ewigen Ordnung hinzuleiten; aber die Gesetze, die man zu formuliren wusste, bezogen sich zunächst nur auf die äussere Erscheinungsweise der himmlischen Bewegungen. Wenn auch Vorstellungen von der wahren Art der Bewegung der Erde um die Sonne gelegentlich aufgetaucht sind: so war weder in der Astronomie der Alten, noch in den musikalischen Beobachtungen des *Pythagoras*, noch in den medicinischen des *Hippokrates* die geringste Spur von einem Verständniss der Mechanik dieser Erscheinungen.

Es folgt während des Mittelalters eine lange Zeit geistiger Unselbständigkeit, Ueberschätzung der deductiven Methode und der Autorität der alten Meister, namentlich des *Aristoteles* und des *Hippokrates.* Das erste neue Erwachen selbständiger Forschung musste ein harter Kampf gegen diese Autoritäten sein, wie ihn *Copernicus* in der Astronomie, *Vesalius* in der Anatomie, *Harvey* in der Physiologie zu führen hatten. Der Fortschritt wurde zunächst hauptsächlich durch die Astronomie herbeigeführt. Die Gesetzmässigkeit der Planetenbewegungen erschien als eine ausserordentlich viel einfachere und verständlichere, seitdem *Copernicus*

die Sonne als den feststehenden Mittelpunct des Systems zu betrachten gelehrt und *Kepler* die regelmässig elliptische Form der Bahn, so wie die einfachen Gesetze, welche die Geschwindigkeit der Fortbewegung jedes Planeten in seiner Bahn bestimmen, aufgefunden hatte. Der entscheidende Schritt aber wurde durch *Galilei* und *I. Newton* gethan, indem sie den Begriff der bewegenden Kraft nach seiner wahren Bedeutung entwickelten, Ersterer that es zunächst an dem Beispiel der irdischen Schwere. Seine Darstellung ist noch eine bildliche, indem er die Wirkung einer continuirlich wirkenden Bewegungskraft mit der einer Reihe kleiner in kurzen Zwischenzeiten auf einander folgender Anstösse vergleicht. *Newton* war im Stande mit Hilfe der schärfer definirten neuen Begriffe der Differentialrechnung die Kraft in rein begrifflicher und ganz scharf bestimmter Form nach Grösse und Richtung durch das Product aus der Masse des von ihr angegriffenen Körpers und seiner Beschleunigung zu definiren. Diese Definition, angewendet auf die Planetenbewegungen, führte diese verwickelte Reihe von Erscheinungen auf das höchst einfache Gesetz der allgemeinen Anziehung aller schweren Körper gegen einander zurück, und stellte damit das glänzendste und imponirendste Beispiel für die einfache und strenge Gesetzmässigkeit der Natur und das Vorbild für die Ziele hin, denen die Wissenschaft nachzustreben habe. Durch das Gravitationsgesetz war der Ort und die Geschwindigkeit jedes Planeten nicht bloss in grober Annäherung, sondern mit den feinsten Messungen übereinstimmend und für unabsehbare Zeiten genau quantitativ bestimmt. Was noch fehlte, war die vollständige Berechnung der sogenannten Störungen, welche die Planeten durch ihre wechselseitige Anziehung auf einander hervorbrachten. Diese Aufgabe wurde hauptsächlich durch *Laplace* gelöst. Was die Theorie anzeigte fand sich in der Beobachtung nachträglich bestätigt.

Möglich wurde die vollständige Anwendung der genannten mechanischen Principien durch die gleichzeitige Entwickelung der Mathematik, nämlich durch *Descartes*, analytische Geometrie, in der alle geometrischen Probleme zu Aufgaben der Rechnung gemacht werden, und durch die von *Leibnitz* und *Newton* entwickelte Analysis, d. h. die Rechnung mit continuirlich veränderlichen Grössen. Man hatte längst die letzten verborgenen Ursachen der Naturerscheinungen als Kräfte bezeichnet, diese als inhärent den Stoffen, als dauernd bestehend und dauernd wirksam betrachtet. In der schon vor *Galilei* und von ihm entwickelten Lehre von der Zusammen-

setzung verschiedener Kräfte, die auf denselben Punct wirken, war die Selbständigkeit jeder einzelnen und ihre Unabhängigkeit von den gleichzeitig vorhandenen andern Kräften anerkannt. Aber bis dahin war die Kraft immer noch ein hypothetisches Abstractum gewesen. Der grosse Fortschritt, der in *Galilei's* und *Newton's* Auffassung lag, war, dass sie nun die Bedeutung einer beobachtbaren Thatsache bekam, der Beschleunigung, d. h. der für die Secunde berechneten Aenderung der Geschwindigkeit, multiplicirt mit der Masse des bewegten Körpers. Wenn *Newton* die Kraft von der Entfernung der Körper abhängig machte, so war darin ein unveränderliches Verhältniss beobachtbarer Thatsachen ausgesprochen: die Beschleunigungen beider Körper werden von ihrer Lage abhängig gemacht. Es zeigte sich bald, dass die ganze Mechanik, die Lehre vom Gleichgewicht, wie die von der Bewegung aller Arten von Körpern aus diesen Principien entwickelt werden konnte, und *Newton's* Gravitationsgesetz wurde das Vorbild, nach dem die Erklärungen auch in allen andern Zweigen der Physik durchgeführt wurden. Erst die Elektrodynamik hat Probleme gestellt, die sich nicht mehr auf dieses Schema zurückführen lassen.

Wenn es die Aufgabe der Naturwissenschaften ist zu suchen, was unabänderlich bleibt in dem Wechsel der Erscheinungen, so hatte die Entwickelung des Begriffes der Kraft und des durch sie als zwingende Macht anerkannten Gesetzes der Erscheinungen, dieser Forderung nur nach einer Richtung hin Genüge gethan. Es lag auch noch die Aufgabe vor, die unzerstörbaren, mit unveränderlichen Kräften begabten Stoffe zu suchen, die wir jetzt "chemische Elemente" nennen. Dass diese Aufgabe vorliege, haben auch die Alten richtig gesehen; aber ihre Versuche sie zu lösen, zeigen nur, wie weit sie von der Einsicht in die richtige Methode entfernt waren. Ihre vier Elemente sind Producte einer Hypothese, die nur die auffallendsten Unterschiede des Aggregatzustandes berücksichtigte, und bei der an eine thatsächliche Prüfung nie gedacht wurde. Eine solche begann, wenn auch nicht zu wissenschaftlichen Zwecken, bei den Alchemisten des Mittelalters. Die Frage, ob Gold aus andern Stoffen zu machen sei, fiel zusammen mit der Frage, ob es Elementarstoffe gebe, die nicht in einander verwandelt werden können. Dass die Elemente nur auf dem Wege des Versuchs zu finden seien, dass ihr Gewicht unveränderlich sein müsse, hat *R. Boyle* (1627–1691) zuerst deutlich ausgesprochen; aber die Unbekanntschaft mit der Natur der Gase, und die damit zusammenhängenden

Schwierigkeiten der Verbrennungstheorie verzögerten noch ein Jahrhundert lang die richtige Durchführung dieser Principien, bis *Lavoisier* gestützt auf *Priestley's* Entdeckung des Sauerstoffs und auf *H. Cavendish's* Nachweis, dass Wasserstoff verbrannt Wasser erzeuge, die Rolle des Sauerstoffs bei der Verbrennung richtig erkannte, und sein neues System durch den Nachweis bekräftigte, dass in der That das Gewicht keiner der von ihm als Elemente hingestellten Substanzen durch Schliessung oder Lösung einer chemischen Verbindung jemals geändert werde.

Damit waren die principiellen Fragen im Wesentlichen entschieden. Die Wissenschaften, welche die lebenden Organismen erforschen, haben sich in den bisher besprochenen Perioden der jedesmaligen Entwickelung der physikalischen und chemischen Theorien angeschlossen. Ihre Aufgabe erschien zunächst zu verwickelt und zu schwierig, als dass von ihnen aus principielle Fragen zu entscheiden waren. Erst in der neusten Zeit ist dies anders geworden. Diese Entwickelung ist aber so neu, dass darüber kaum Geschichte zu schreiben ist.

INTRODUCTION TO VOLUME VI.

It is instructive to revert to the modes of thought and of perception that were prevalent in ancient times; but unexpected difficulties immediately present themselves in any such attempt. Many things that we have known and understood from our earliest childhood, apparently without aid or suggestion from without, and which, therefore, appear to us to be quite simple, and indeed self-evident, we are astonished to discover were unknown and unperceived by the leading men of the most intelligent nations of antiquity. It thus becomes evident that we are indebted, to a much greater extent than is usually admitted, to the labours of past generations.

Thoughts like these crowd upon the mind when we look back on the history of Science. Nothing is simpler than that method of investigation which, after many erroneous paths had been successively pursued, is now adopted in every scientific research. This method, usually termed the *inductive method*, is in fact only the procedure which the healthy human understanding is accustomed to employ in the practical operations of daily life without special instruction, and unmistakeable traces of the application of which may be observed in any of the more intelligent animals. We endeavour by experiment to ascertain how the things by which we are surrounded behave under various circumstances; and, in particular, how far and in what way we are able to influence them; and we anticipate that, under new conditions, the course of events will be similar to that observed in all previous cases of a sufficiently similar nature. The difference between scientific investigation and ordinary inquiry lies in the circumstance that in the latter case we merely observe the facts presented to us, and are satisfied with the slowly fading impressions of the past as they may linger in our memory, whilst the only means by which we form an estimate of

quantitative and qualitative differences is derived from the mode and intensity of the sensorial impressions that have been made upon our mind.

In scientific research, on the other hand, we endeavour, so far as may be practicable, to obtain a complete knowledge of particular instances, and to ascertain clearly the variations to which they are liable, whilst at the same time we observe whether these variations are spontaneous or can be intentionally or experimentally produced. We then seek to define with clearness and precision the conditions upon which each variation depends; whether a certain effect follows a supposed cause or fails to appear, and if it appear, to what degree or amount; in fine, we continue our inquiries until we are able to anticipate the result in every future case of a similar nature. We endeavour thus to obtain accurate conceptions, to fix them by oral and written description, and at the same time to expand and develop our knowledge of each particular by comparing it with the statements of our contemporaries and predecessors. We are thus certain that every deviation from a law supposed to be correct will arouse attention in proportion to the belief in the accuracy of that law. The results already obtained by scientific inquiry are thus subjected to constant control in regard to their accuracy, and are always amenable to improvement. But all this is, in point of fact, nothing else but an extremely careful and consequent performance of that which an intelligent man is accustomed to execute without scientific training in the performance of the most ordinary acts of everyday life.

It is not surprising that by the tyro in science the effort of the mind is held to be greater in proportion as the laws which he understands and can apply are more comprehensive and exact. The general principles of Mechanics in their abstract mathematical form appear, no doubt, to be far enough removed from the simplicity of popular laws derived from simple experience. They constitute the magic spell by whose aid the moderns have compelled the opposing forces of Nature to submit to their control; yet they have undoubtedly been acquired in the same way as the minor appliances and handy inventions of the household and of the workshop.

That the ancients possessed less scientific knowledge than we who inherit what they acquired need not surprise us. We should rather wonder that in many instances they should have been acquainted with so much than be surprised at their knowing so little. But what never ceases to excite our astonishment is, that these nations who, in the formation of their language,

in their laws and in their general polity, in the writing of history, and in the philosophical discussion of abstract ideas, stand no whit behind us—who were, moreover, in many branches of art decidedly our superiors—should exhibit so remarkable an incapacity of discovering the correct mode of solving scientific problems, and even of perceiving the more important questions that arise. We seem to feel that the method which has ultimately yielded so rich a harvest to us, appeared to them too simple and uncomplicated to excite hope, and that they believed they could obtain superior results by deep cogitation and mental exertion.

That they were not wanting in that faculty of observing the phenomena around us which I have already termed common sense without scientific training, I need scarcely demonstrate. That faculty is nearly allied to Art and the power of representing characteristic types in an artistic manner; for such types represent order and law. A remarkable example of such artistic, rather than scientific exposition, is exhibited in the works of Hippocrates. He attempted to discover and describe the order and mode in which the course and distribution of disease occur, and he thus constitutes the first example of order, or classification, in a department of knowledge, in which the separation of the various co-operating causes is undeniably the most difficult of all. He was not, however, entirely destitute of scientific training. A fair amount of sound medical knowledge was already possessed by the school of the Asclepiads, with which he appears to have been acquainted; so that, in point of fact, he knew what there was to be known in his time. But in forming an estimate of him, it is clear that Hippocrates is a great physician, not on account of his theoretical knowledge, but in spite of it. He refers to his theories only when they agree with his facts; when they do not, he passes them over in silence. His pupils and successors, however, who were defective in the essential point of his character, namely, his extraordinary talent of observation, sought for his greatness exactly where he was weakest, that is, in his theories, and drew from them deductions which, whilst they did not attempt to substantiate by facts, they nevertheless considered to be true. The same thing has always occurred whenever a great master of observation has arisen, and may be regarded as a characteristic sign of a step in the progress of knowledge, and as showing that science had not yet arrived at a clear perception of the true principles by which it should be guided.

The Greeks undoubtedly made the first steps towards the discovery of these principles. In those sciences which rest on observation Aristotle rightly saw that it was necessary to obtain in the first instance, as general and complete a view as possible of the facts, and to collect the experience of preceding ages; and he exerted himself to accomplish this in Natural History, and in part also in the Physical Sciences, just as Galen did in the case of Medicine. Both of these masters exhibited remarkable penetration and sound judgment. In a similar way Socrates and Aristotle traced correctly the first lines of the theory of consciousness; the former by pointing out and giving examples of the importance, in a scientific point of view, of sharply defined conceptions illustrated by examples; the latter by developing the true principles of the deductive method, namely, the development of consequences from admitted data. The progress made by both in this direction produced a profound impression on their contemporaries and excited unreasonable expectations. It is scarcely possible for us to conceive a condition of mind in which ordinary logical propositions constituted new and surprising feats of mental insight; whilst at the same time it may be freely admitted, that no slight effort at abstraction was required to clothe them in clear and definite language for the first time.

The deductive method is most appropriately employed when accurate and sufficiently numerous data have been obtained, from which conclusions in regard to special cases may be drawn. This was only accomplished by the ancients in the case of one subject, that, namely, of Geometry, which it appears was first worked out with practical objects in view by the Egyptians, from whom it was borrowed by Pythagoras, who again taught it to the Greeks, being ultimately worked up into a very perfect scientific form by Euclid. I have elsewhere endeavoured to show that the axioms of Geometry, those general propositions from which all the others may be deduced, were really drawn from experience, and were not created by the exercise of pure reason. It may be added, that a few physical laws, in a limited sense, were actually known to the ancients. Pythagoras was acquainted with the simple relations that the length of strings bear to consonant musical intervals. Archimedes knew the laws which govern the reflection of light, and many of the laws of Statics; for example, those of the balance, of the lever, and of the weight of heavy bodies immersed in fluids. He founded on his knowledge of the last the methods which are still

employed to determine specific gravity. Hero, again, knew the effects of pressure of the air; and Claudius Ptolemaeus the laws of the refraction of light in the air.

Mankind early acquired a tolerably exact knowledge of the apparent motions of the sun, moon, planets, and fixed stars, in the heavens. In this knowledge the Greeks were preceded by the Egyptians and Babylonians. The Calendar for the estimate of civil time underwent gradual but constant improvement, and was made to agree with the movements of the sun and moon. Astronomical researches were peculiarly adapted, in the exact and unchangeable regularity they showed to exist in the mighty operations of Nature, to conduct the mind of man to seek for perpetual order; but the laws which it was desired to formulate referred, in the first instance, only to the apparent movements of the celestial bodies.

But even if it be admitted that some representation or conception of the true nature of the motion of the earth around the sun has occasionally arisen, neither in the astronomy of the ancients, nor in the musical observations of Pythagoras, nor in the medical knowledge of Hippocrates, is there the slightest trace of an intelligent comprehension of the mechanics of these phenomena. In the Middle Ages a long period followed of mental imbecility, of over-estimation of the deductive methods, and of the authority of the old masters, especially of Aristotle and of Hippocrates. The first re-awakening of independent inquiry exhibited itself in a severe contest against the old authorities, which was conducted by Copernicus in Astronomy, by Vesalius in Anatomy, and by Harvey in Physiology.

Progress was first made in the science of Astronomy. The regularity of the movements of the planets appeared wonderfully more simple and intelligible after Copernicus taught that the sun must be regarded as the fixed central point of the system; and after Kepler demonstrated the regularly elliptical form of the path of each planet, and the simple laws which determine the rapidity of its movement in its orbit. The decisive step was, however, made by Galileo and by Newton, when they developed in its true significance the conception of motion. The former adduced examples of terrestrial gravity; but his conception was still material, since he compared the effect of a continuously operating moving force to a series of small impulses succeeding one another at short intervals. Newton was in a position, with the aid of the better defined and novel ideas of differential calculus, to define force in a conceivable and quite distinct form, and to show that,

however various it might be in amount and direction, it was always the product of the mass of the body multiplied into its velocity. This definition, when applied to the planetary motions, referred their complicated phenomena to the extremely simple law of the general attraction of all material substances to each other; and thus gave the most brilliant and imposing example of the simple and strict orderliness of Nature, whilst it constituted also an example of the object for which science should strive. The law of gravitation not only enabled a coarsely approximative estimate of the position and rapidity of each planet to be obtained, but showed that these were actually in accordance with the most delicate measurements of time and space. That which was still defective was the means of exactly estimating the so-called disturbances exerted by the planets upon each other, owing to their varied and mutual attraction. This problem was essentially solved by Laplace. What was required by theory was corroborated by subsequent observation.

The complete application of the above-mentioned mechanical principles was materially furthered by the coincident development of Mathematics, and especially the analytical geometry of Descartes, in which all geometric problems were made problems of calculus; and also by the method of analysis developed by Liebnitz and Newton, that is to say, calculations with continuously changing amounts.

The final and most recondite causes of natural phenomena had long been characterised as forces; these forces were regarded as inherent to matter, as persistent and permanently active. In the doctrine of the composition of forces acting on a single point, which existed before Galileo, and was developed by him, the independency of each force, and its distinctness from other coincidentally present forces, was clearly recognised. But force was still always regarded as a hypothetic abstraction. The great advance contained in the explanation given by Galileo and by Newton was, that the term force acquired the significance of something capable of being observed; the acceleration of movement, that is, the variation per second, equalling the velocity multiplied into the mass of the body moved. When Newton considered force to be dependent on the distance separating bodies, he expressed an invariable relation of observable facts. The acceleration of the movement of both bodies, on the other hand, he showed to be dependent upon their position. It soon appeared that the whole of Mechanics, as well as Dynamics, could be developed from these principles; and Newton's law of

gravitation was the type in accordance with which explanations were given in all other branches of Physics. Electro-dynamics has however recently presented problems which cannot be referred to this scheme.

As it is the aim of natural science to discover the invariable amidst the variable, the development of our conception of force and of the laws of phenomena, over which it exerts control, progress only in one direction. The problem still remains to discover the indestructible, *i.e.*, those materials endowed with unalterable force, which we now term "chemical elements." That this problem existed was clearly seen also by the ancients; but their endeavours to solve it served only to show how far removed they were from the right method of investigation. Their four elements were products of an hypothesis which only took into consideration the most striking differences of outward appearance, and was never attempted to be definitely proved. Such proof commenced, though it was not conducted by them with a strictly scientific object in view, with the alchemists of the Middle Ages. The question whether gold could be made from other substances was synonymous with the question whether there are elementary substances capable of being transmuted into each other. That the elements are only discoverable by experiment, and that their weight is invariable, was first distinctly expressed by R. Boyle (1627–1691); but ignorance of the nature of gases and the associated difficulty of the theory of combustion delayed for a century the correct application of this principle. Lavoisier then, basing his views on Priestley's discovery of oxygen, and upon the proof furnished by H. Cavendish, that water was produced by the burning of hydrogen, clearly recognised the part played by oxygen in combustion, and supported his new system by evidence that the weight of none of the substances he admitted to be elements underwent change, either in entering into or separating from a chemical combination. The main questions were in this way essentially decided. The sciences which deal with living organisms accept the physical and chemical theories of the present time; but the problems with which they have to deal appeared, in the first instance, to be too complicated and too difficult to enable their principal questions to be solved by these means. It has only quite recently turned out otherwise. This development is, however, so recent that no historical details respecting it can be given.

H. HELMHOLTZ.

LIST OF PORTRAITS

IN THE

SIXTH VOLUME

TABLE OF THE NATURAL SCIENCES.

THE HUNDRED GREATEST MEN OF SCIENCE.

I.—MATHEMATICIANS.

SCIENCES OF CALCULATION: MATHEMATICS, ASTRONOMY, PHYSICS.

Antiquity: Euclid, Hero, Archimedes, Apollonius, Eudoxus, Aratus, Hipparchus, Ptolemy.

Middle Ages: Albategnius, Nasir Eddin.

Renaissance: Copernicus, Tycho Brahé, Kepler, Halley, Huyghens, Bernouilli. Bradley, Pascal, Galileo, Porta, Gilbert, Torricelli.

Modern Times: Clairaut, Euler, Delambre, Newton, Hooke, La Grange, Franklin, Young, Herschel, Faraday, Volta, Galvani, Ampère, Rumford, Arago, Oersted, Laplace, Gauss.

II.—PHYSICIANS AND CHEMISTS.

SCIENCES OF EXPERIMENT: CHEMISTRY, PHYSIOLOGY.

Antiquity: Hippocrates, Erasistratus, Hierophilus, Galen.

Middle Ages: Avicenna, Marcus Græcus, Geber, Roger Bacon.

Renaissance: Vesalius, Fabricius, Harvey, Malpighi, Paracelsus, Van Helmont.

Modern Times: Boerhaave, Hunter, Haller, Stahl, Bordeu, Bichat, Gall, Bell, Müller, Black, Cavendish, Bergmann, Priestley, Scheele, Davy, Lavoisier, Dalton, Gay-Lussac, Berthollet, Berzelius, Ritter, Liebig, Graham.

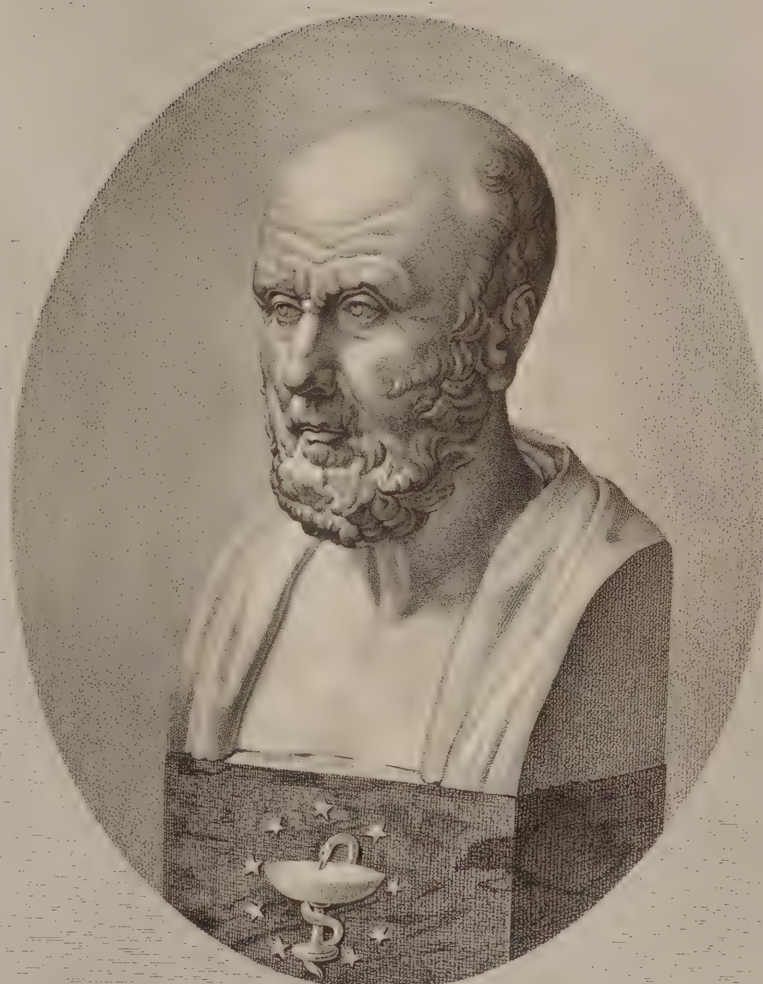
III.—NATURALISTS.

SCIENCES OF OBSERVATION: GEOGRAPHY, MINERALOGY, BOTANY, ZOOLOGY.

Antiquity: Theophrastus, Eratosthenes, Strabo, Pliny.

Renaissance: Gesner, Cæsalpinus.

Modern Times: Leuwenhoek, Tournefort, Linnæus, Buffon, Bonnet, Werner, Hutton, Lyell, Jussieu, De Saussure, Haüy, Humboldt, Cuvier, Lamarck, Erasmus Darwin, Geoffroy Saint-Hilaire, Blainville, Von Baer, Wolff, Schleiden, Agassiz.



Hippocrates

HIPPOCRATES

B.C. 460?-357?

THE FATHER OF MEDICINE

The art of healing, it is obvious, must have been in its origin coeval, or nearly so, in some rude form, with the earliest human need of its exercise. Such a phrase as "the Father of Medicine" without explanation, is therefore misleading. It must of course be accepted *cum grano*, as we say. The fact is that long before the age of Hippocrates, the practice of medicine had made large advances from the condition of primitive rudeness which we are compelled to assume. It had become in Greece the business of a special and numerous class, the Asclepiadæ, a priestly class, who carefully kept their own secrets from profane understandings, and handed them down from father to son. They were scattered in small bands all over Greece, but had their headquarters at Epidaurus, on the coast of Argolis, where stood the principal temple of their god Asclepios. Homer speaks of him as the "blameless physician," and says nothing of his origin. After times venerated him as the son of Apollo; and the human personality was hopelessly lost in the clouds of myth and legend which gradually gathered around it. One of the offshoots from the Epidaurian temple and group of priests, was to be found in the small island of Cos, a gem of the Ægean; and here was

born the great master, of a family who practised the healing art for several centuries, some members of it attaining a great reputation.

For the story of his life, we have, unfortunately, no contemporary or even trustworthy authority. We can, therefore, only tell the tale as it is usually told without saying how the truth may be.

Hippocrates was born about B.C. 460 (Ol. 80, 1), the year of the birth of Democritus. He lived in the greatest age of Greece, and was contemporary with Herodotus, Socrates, Thucydides, Plato, Æschylus, Phidias, and their compeers. His education was not confined to professional subjects, but embraced logic, physics, geometry, and even philosophy and rhetoric, which he studied under Gorgias. He spent many years in travelling, especially in Macedonia, Thrace, and Thessaly, investigating the virtues of "simples" and the action of remedies in the treatment of disease. He visited the temple of Diana at Ephesus, and transcribed the medical registers or records preserved there. It was customary to keep accounts of the maladies of those who resorted to the temples of health, and of the remedies which had been effectual. These records formed the quasi-medical literature of the time.

The reputation of Hippocrates grew to a great height. Kings and nations coveted the presence of so mighty a healer and helper. Perdiccas II. of Macedonia consulted him; Artaxerxes of Persia offered him immense gifts, money and towns, for his services; the Illyrians summoned him to save them from pestilence: the Abderites called him to see their "mad" philosopher Democritus, whom he found to be the sanest man among them; and the Athenians voted him a crown of gold, maintenance for him and his descendants at the Prytaneum, and initiation into their mysteries, seldom given to foreigners. Hippocrates did not care for gifts. He declined the invitation of the Persian king, and the remuneration offered by the Abderites. He prayed the gods to give him, not money, not pleasures, but a long life, with good health, success in his art, and a lasting fame. His desire was fulfilled, and the nations have given

"Eternal honour to his name."

Dante, it is worth noting, has placed him in the first circle (Limbo) of his "Inferno," among the wise and good of old, the "souls of mighty worth" who lacked nothing but the rite of baptism for admission to the paradise.

Hippocrates is depicted to us as a man of great bodily vigour, with capacity of immense labour without injury ; and of astonishing power and penetration of mind, so that he never despaired of conquering the toughest problems in his science, by persistent endeavour. He lived to a great age, variously stated at 85, 90, 104, and 109 years, and died at Larissa in Thessaly.

With Hippocrates and his race, the Asclepiadæ, is associated the great revolution by which the priestly monopoly of the practice of medicine was broken up, and the pursuit of it was thrown open to all who desired it. This is shown by a clause in the " Oath " exacted of his pupils, one of the pieces most certainly genuine among the writings attributed to him. To the same end, the opening of knowledge to all, he wrote his medical works, the earliest that have come down to us, and which, after all the advances made through two thousand years, are still studied with reverence. In his writings, medical science appears at a height of development for which nothing that we know of its earlier state furnishes adequate explanation. On such grounds as these firmly rests his claim to the title which the ages have awarded him, of " Father of Medicine." In the long process of development of medical science, his teaching forms one of the greatest forces. He summed up in himself all that was known before, added immensely to the store by his own study and practice, and so handed on an almost newly constituted science, to those who came after him.

Among the most noteworthy features of his practice and teaching, are the following. He paid special attention to the observation of symptoms in disease, both those precedent and those concurrent (*prognosis* and *diagnosis*); and in acuteness of observation and accuracy of description he has never been surpassed. Most of the forms of disease which he described and named still bear the names he gave them. He held the four humours (or fluids) of the body to be the original seat of disease ; health depending on a due proportion and proper quality of these humours. He taught also that there is a relation between them and the four seasons of the year. This doctrine of the " humours," accepted and extended by Galen, held its ground for more than thirteen centuries, and traces of it still remain in our common speech. Hippocrates was the first to insist upon the important influence of diet, and would frequently trust to its regulation as the sole remedy in disease, especially where the constitution was strong. He had a firm faith in the

restorative tendency of nature (*vis medicatrix naturæ*). There is no evidence that he knew of the pulse as an indication of states of the body. He was the first to treat anatomy as a science, although there is no evidence and little probability that he practised dissection of human subjects. He was well versed in surgery, had much skill in dealing with fractures, and practised all the operations known in his time, except lithotomy. This appears to have been left for some reason to other hands than physicians. He discontinued the superstitious method, in vogue up to his time, of treating some cases by action on the imagination, and confined himself to rational methods. He greatly enlarged the *Materia Medica* of his time; three hundred articles being mentioned in his writings. But it is difficult now to understand in some cases the accounts left of his medical preparations. Hippocrates was more than a great physician; he was a philosopher and a great man. Scattered through his works are abundant proofs of this, in weighty axioms, acute observations, and pithy sayings. Our hackneyed quotation, "Life is short, Art is long," first appears in literature as part of his first aphorism.

Of the numerous pieces which have come down to us under his name, hardly a fourth are admitted as genuine. Attempts to distinguish these began to be made at an early period. Editions of the whole or of separate portions, and translations into various languages are almost numberless, and the commentaries upon them make a formidable mass of literature. A complete German translation, by Grimm, appeared in 4 vols. 8vo. between 1781-1792. A complete French edition, with translation, introduction, medical commentaries, and philological notes, by M. Littré, was published in 10 vols. 8vo., between 1839-61. This elaborate and scholarly work is at present unrivalled. In 1849 an English translation of the genuine works, by Adams, with a preliminary discourse and introductions, in 2 vols. 8vo., was published by the Sydenham Society.

EXTRACT FROM HIPPOCRATES

ON THE ART OF MEDICINE.

All who are acquainted with it will admit that there are two classes of diseases: one affecting the extreme parts, and few in number; the other is in vast amount, and attacks the parts that are internal and concealed, wherein they manifestly differ from the former, which are apparent to sight and touch by tumours, redness, &c.

The human body has many cavities: thus, two exist for the reception and discharge of food, with many others known to those who have studied the subject. All those fleshy rounded parts called muscles are cavernous; all parts in fact in which there is defect of continuity are cavities, whether covered by flesh or skin, and they are filled with air (*spiritus*) in health, but in disease with unhealthy humour. Such fleshy parts are the arms, thighs, etc. Even such parts as are not fleshy have a similar structure. For instance the liver, concealed in the abdomen, the brain in the skull, the lungs in the thorax, all have cavities with subordinate divisions, or vessels, filled with humours of a healthy or unhealthy tendency. There are moreover nerves and vessels innumerable passing to the bone; and ligaments and cartilages belonging to the joints wherein the bones move, and which are moistened by a glairy fluid emitted from small cavities. Now none of these parts are apparent to our sight, and hence the above division of diseases into concealed and apparent.

Archimedes

ARCHIMEDES

B.C. 287-212

FOUNDER OF PHYSICS

The preservation and transmission of ancient books, through all the destructive revolutions that have swept over empires and nations, is one of the most astonishing facts in the history of the human race. All the more astonishing when we consider that they existed only in the frail form of manuscripts, and that the number of persons seriously interested in most of them and concerned about their safety was really very limited. Many, indeed, have perished. But the wonder is not that some of these "ships of time," as Bacon calls them, laden with priceless treasures of truth and wisdom, fit for the nourishment and the healing of the peoples, should have gone down to the unsearchable abysses, but that so many have escaped, and after voyages of millennial duration have found at last safe havens.

Terrible was the risk to accumulated treasures of this kind when the city of Constantine, the new Rome, a centre of civilisation and literary culture, at length fell into the hands of the Turks. But Greek scholars had already begun to resort to the seats of reviving culture in the great cities of Italy; and in their enforced final flight they carried with them such of the precious manuscripts of old as they could snatch from impending

destruction. Among these treasures thus carried to Italy were the writings of Archimedes, the greatest name among ancient geometricians. Copies of them falling into the hands of Regiomontanus, he took them to Germany; and, printing having meanwhile been invented, the *editio princeps* of Archimedes was published at Basel, in Greek and Latin, in 1544. This was followed within the next 150 years by editions at Paris, Venice, Messina, Palermo, and London. And these were all surpassed by the first complete and most splendid edition, the folio of Torelli, printed at the Clarendon Press in 1792. The sight of this folio may well call to mind the reply which Archimedes made to Hiero, when asked if he could not make these things easier: "There is no royal road to geometry." The greatness of Archimedes, like that of Newton, is of a kind which lies beyond the apprehension of more than a very few minds in each generation.

He was born at Syracuse B.C. 287 (Ol. 123, 2), a few years before the death of his greatest predecessor, Euclid. On his father's side he was related to Hiero II., King of Syracuse; but his mother was of an obscure family. His ruling passion revealed itself in his youth, in earnest absorbing devotion to the study of geometry. He was a follower of Plato in philosophy, and, like him, set the research of truth far above the pursuit of gain or any profit to the mere outward life. While men praised him without stint on account of his marvellous mechanical inventions, he thought lightly of these, felt almost ashamed of them, called them trifles and playthings, in comparison with those lofty far-reaching speculations in the sphere of pure intellect in which he delighted, and in which he was grandly alone; herein presenting a contrast to Bacon, who valued the study of geometry only for its practical applications. He is said to have travelled in Egypt and in other countries before finally settling at his native place. In Egypt he invented the screw bearing his name, for drawing off water, now called by the Germans the "water-snail." He is said also to have applied a screw to the purposes of navigation.

To him we owe the discovery of the principle that a body plunged into a fluid loses weight equal to that of the fluid displaced. With this discovery is connected the story of the golden crown made for Hiero, which he suspected to be alloyed with silver. The test for gravity occurred to Archimedes while at the bath, and with irrepressible joy he rushed to his home, forgetting to dress, and shouting "I have found it" (*Eureka*). One

of his most remarkable achievements was the construction of a sphere to exhibit the movements of the heavens, a quasi-orrery. This is noticed by Claudian in a striking passage of his poems, and also by Silius Italicus and Ovid. He made a very near approach to a precise determination of the ratio between the diameter and the circumference of a circle; determined the relation between a circle and an ellipse, and the proportion between the solid contents of a sphere and of a cylinder circumscribed. He devoted much attention to the mensuration of conic sections, expressed his familiarity with the power of the lever in the saying, "Give me a standing place and I will move the earth itself;" and among the engines which he devised for the defence of Syracuse, when besieged by the Romans under Marcellus, were burning glasses by which to set the enemy's ships on fire. It is most likely that there is much exaggeration in the traditional accounts of his machines at this siege; he wrote none himself, and it is certain that we find no mention of the burning mirrors before Tzetzes, who lived fourteen centuries later. Buffon, to test the possibility of such action, constructed, in 1747, a burning mirror, with which he could set fire to wood, or melt lead, at considerable distances. Archimedes is the only ancient writer who has left anything satisfactory on the theory of Mechanics and on Hydrostatics. These subjects are treated in his works on centres of gravity of lines and planes, and on the equilibrium of bodies plunged in a fluid. Even the germs of the calculus are found in his speculations.

The rare faculty possessed by Archimedes of solving hard problems had given rise, in the time of Cicero, to the phrase, "Archimedean problem," in the sense of enormously difficult. To measure and appreciate the greatness and achievements of Archimedes it is necessary to have exact knowledge of the state of his science before his time. Nothing remains to us but Euclid, with some fragments of his commentators, and a solitary work of Pappus. Leibnitz, with adequate intelligence, says: "Those who have attained to the power of comprehending Archimedes will be less astonished at the discoveries of modern men."

When Syracuse was besieged by Marcellus (214 B.C.) so efficient were the services rendered by the great thinker and inventor, Archimedes, that the operations of the attack were wholly frustrated, and the siege was converted into a blockade. The city held out for two years, and was taken in 212. Archimedes was among the slain. The accounts of his death vary

in detail, but agree in the essential fact that, while absorbed in his mathematical studies, he was surprised and killed by a Roman soldier. Marcellus had given particular orders to spare him and his house, but in vain.

On the monument erected to him in the burial place was cut, by his own desire, the figure of a sphere with a cylinder circumscribed, and a record of the proportion between the contents of the two. Less than a hundred and forty years had passed when Cicero, a young man and enthusiastic student, held his first public office, the quæstorship, in Sicily. Before leaving the island he wished to see the tomb of Archimedes. It was already forgotten. The magistrates knew nothing about it. They led the eager inquirer to the old burial place, and allowed him to search. He soon detected in a spot overgrown with briars a small column bearing the figure of the sphere and cylinder, with the inscription partly illegible. "This," said he, "is what I was looking for. And this noble and once learned city had known nothing of the monument of its greatest citizen if it had not been discovered to them by a native of Arpinum." A noteworthy illustration of Crabbe's reflection—

> "And monuments themselves memorials need."

ARCHIMEDES

CONTENTS OF HIS WORKS

Galen

GALEN

130-200 (?)

ANATOMICAL SCIENCE

Manifold is the interest attaching to the old city of Pergamos in Asia Minor. Its origin lost in mythical remoteness of time; its singularly lovely situation and environment; its colony of Asclepiads from Epidaurus, which became in the course of centuries one of the most famous of medical schools; its flourishing kingdom, which rose rapidly and maintained itself for a century and a half; its library and school of learning, once rivalling those of Alexandria; its early Christian church, one of the seven addressed by the author of the Apocalypse; the existing remains of its Acropolis, temples, churches, amphitheatre and other buildings (marvellous fragments of its sculptures at this moment exciting the admiration of Europeans); its invention of parchment (*Charta Pergamena*) as writing material; such claims has Pergamos on the enduring memory of men. And one other claim, strongest of all—it was the birthplace of a great man. And while Asclepiads, school, library, temples, fortress, churches were all vanishing or crumbling to dust, the name and fame of Galen rose higher and higher and, in the sphere of medicine, ruled the civilised world with an authority beyond question for more than twelve centuries.

Galen (*Claudius Galenus*), after Hippocrates the greatest of ancient writers on medicine, was born A.D. 130. He was the son of Nikon, an architect and mathematician, wealthy, honoured and of cultivated mind. His mother is less favourably portrayed. She is said to have been a Xanthippe. Trained at first for a philosopher, his course was altered in his seventeenth year, and he began the special study of medicine under teachers in his native city. After the death of his father (about 149) he set out on a course of studious travel, visiting and making some stay at Smyrna and at Alexandria, then the seat of the best medical school in the world. Returning to Pergamos (158) he was at once appointed physician to the school of gladiators. After practising there for several years he went to Rome. In the imperial city his rare skill in anatomy and some remarkable cures which he effected ensured him high distinction; and also brought upon him a storm of jealousies, envies and ill-will from those whose credit and emoluments were imperilled. Galen was ridiculed as a theorist (not altogether without reason), was accused of magic (he thought much of amulets and dreams), and was called utterer of paradoxes and worker of wonders. He is said to have carried himself with offensive vanity and infinite scorn. Considering the usual position of genius among the dunces, this is not much to be wondered at. It is, however, clear that Galen had not the simple greatness of his master Hippocrates; did not equal him in reverent regard for facts, but was anxious at all cost to shine; and of things which he did not really understand would sometimes give hypothetical explanations.

He was at Rome on this first occasion about four years; and he had no sooner returned to Pergamos than he was summoned to attend the emperors Marcus Aurelius and Lucius Verus at Aquileia. Driven thence by the plague, Galen accompanied the emperors to Rome (170). He was charged with the care of the young Commodus, and remained at Rome for some time. Dates are unobtainable; but it is known that he attended M. Aurelius, his son and Severus, and that at Rome he lectured and wrote some of his most important works. He appears to have gone once more to Pergamos; but where he died, and when, is unknown. He is stated by Suidas to have lived to the age of seventy, which would fix his death to the year 200; and by Abulfaragius to have lived to the age of eighty, thus dying in 210.

Galen wrote in Greek, with all the dialects of which he was familiar. He was also acquainted with the Latin, Ethiopic and Persian languages. It is stated that his medical treatises numbered 500, and that his works on philosophy, logic, &c., numbered about half as many. Of the published treatises 83 are recognised as genuine, 19 are held to be doubtful, and 45 certainly spurious. There are besides these, many volumes of fragments and of notes on Hippocrates. His works were early translated into Arabic, and he became supreme in the East as well as in the West. Most of his extant works are in Greek, some in Latin, and a few in Arabic. One of the most remarkable proofs of the commanding position of Galen is the fact that all the medical sects which existed before his day disappeared, and after him all were Galenists. Of his supremacy there is a striking instance in English medical history. In the middle of the sixteenth century a physician who dared to question the infallibility of the master was cited before the Royal College of Physicians and compelled to sign a recantation.

Of all Galen's writings the most valued are those on anatomy and physiology; and of these the most important are the treatises "De Anatomicis Administrationibus" and "De Usu Partium Corporis Humani." The latter is especially remarkable for the large knowledge and acuteness of thought displayed in it. In some passages a deep religious feeling shows itself. "In writing these books," he says, "I compose a hymn to the Author of nature. True piety doth not consist in the sacrifice of hecatombs or the burning of a thousand exquisite perfumes in His honour; but in recognition and proclamation of His wisdom, almightiness and goodness."

In philosophy Galen was an eclectic. He rejected the current Epicureanism, and studied the Stoics, the Academics and the Peripatetics. He held that a physician ought to be also a philosopher. In medicine he was a follower of Hippocrates, whose chief doctrines he adopted; as for example, those of the four humours, of critical days, of disease as contrary to nature, the importance of diet, &c. He wrote much clear exposition and sound criticism of his master's teaching. He attached much importance to the pulse as an indicator; and on this subject he is the first and highest authority. He made large advances in anatomy; introduced many new terms which have kept their ground; was the first to dissect a great number of muscles and demonstrate their position and direction; and though the subjects of his dissection were, with very rare exceptions, only animals, and

chiefly of the ape tribe, his books on anatomy were the best existing between the second and fifteenth centuries. In "Materia Medica" he was not so good an authority as Dioscorides. His pharmacopœia consisted chiefly of organic substances, and included no chemical preparations. Galen was a persevering observer and collector of facts and a great master of generalisation. He lived a sober and temperate life, was humane in his practice, not respecting persons, but caring as much for the beggar as for the king. There is no evidence that he had much intercourse with the Christians; but in one of his extant fragments he mentions the "sect" and praises their temperate and chaste lives.

The first Latin edition of Galen was published at Venice in 1490, in 2 vols. folio. The *editio princeps* of the Greek text was the Aldine, at Venice, 5 vols. folio, in 1525. It has been three times republished, the most recent and best edition being that of Kühn, at Leipsic, 20 vols. 8vo., in 1821–33. An edition of the Greek with a Latin version appeared in Paris, in 13 vols. folio, in 1639. The commentaries written upon his works are very numerous and voluminous.

Fast bound in the chains of the Galenic system, the science of medicine was for ages paralysed. There was need of a revolution before a fresh advance in real knowledge was possible. In the fifteenth century came the awakening. Fresh study of the greater ancients was followed by the opening of the recovered Bible. The dreams and investigations of the alchemists were the germs of chemical science; and when the new iatro-chemists began their labours, Galenism was doomed. In 1520 Luther burnt the Pope's Bull at Wittenberg, and in 1526 the coarse, drunken Paracelsus began his career of Professor of Physic and Surgery at Basel by burning, in the presence of his pupils, the works of Galen and Avicenna. He called them vain dreams, and invited his pupils to study "the open book of Nature which God's finger had written." In spite of all his faults and errors, "the word of Paracelsus," says the historian, "gives to the century its direction."

GALEN

CHRONOLOGY OF HIS LIFE

130	BORN AT PERGAMUS.	
147	BEGAN TO STUDY MEDICINE	AGE 17
158	ESTABLISHED PHYSICIAN AT PERGAMUS . . .	„ 28
162	VISITED ROME	„ 32
167	LEFT ROME; VISITED AQUILEIA	„ 37
169	RETURNED TO ROME WITH M. AURELIUS . . .	„ 39
170–7	"DE USU PARTIUM," ETC.	„ 40–7
191	"DE LIBRIS SUIS DE COMPOSITIONE MEDICAM;" BOOKS BURNED	„ 61
192–3	DELIVERED LECTURES	„ 62–3
200	DIED.	„ 70

GALEN

USES OF THE DIFFERENT PARTS OF THE BODY

ABSTRACT OF CONTENTS.

Books I. and II.—Introductory. The hand of man, from its peculiar structure, is set forth by Galen as the chief source of his great superiority over every other animal.

Book III.—The lower extremities. Galen expatiates on man's superiority from having two legs instead of four.

Books IV. and V.—Consideration of the stomach, liver, and other organs of nourishment. The liver is the largest and most surprising organ in the body. The pancreas and kidneys are treated, completing the subject of digestion and excretion.

Books VI. and VII.—The thorax with its contents, the heart and lungs, are described. Fish are mute, having no lungs. In respiration something is discharged of a noxious character.

Books VIII. and IX.—The head. Animals with a neck are those that have lungs. Common purpose of the head. Instruments of sense. Cerebral nerves. Cerebellum. The cerebrum, its arteries, veins, and nerves.

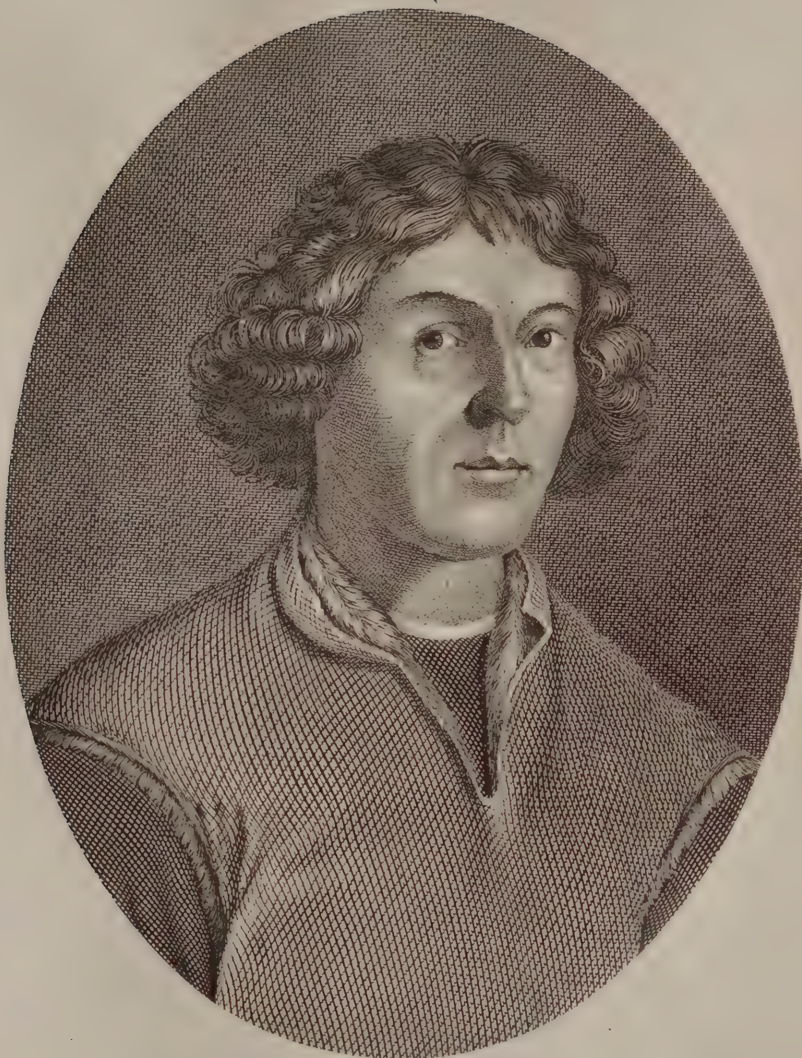
Book X.—The organ of vision.

Books XI., XII., and XIII.—The face. Neck. Vertebræ. Spinal marrow and spinal nerve.

Books XIV. and XV. treat of generation and the formation of the fœtus.

Book XVI. treats of the distribution of the arteries, veins, and nerves through the entire body. These Galen calls the *common instruments.* The great artery rises from the heart, the vein from the liver, and the spinal marrow and nerves from the brain.

Book XVII. is a sort of recapitulation of the preceding books.



COPERNICUS

COPERNICUS

1473-1543

FATHER OF MODERN ASTRONOMY

Nicholas Copernicus was a native of Thorn, which, at the time of his birth, formed part of the dominions of the King of Poland. Historians have long discussed the origin of this great man. Some assert that his father was a serf, while others pretend that he was descended from a noble family, as if an illustrious pedigree could, like genius, confer glory and immortality. The truth seems to be that he was of mixed descent. His father was apparently of the Sclavonic race, as he was certainly a Bohemian by country; his mother was an undoubted German. His parents took care that he should receive a first-class education. After studying classics in the college at Thorn, he went, at the age of eighteen, to follow the courses of philosophy and medicine in the University of Cracow. There the lectures of Albert Brudzewski inspired him with a passion for the science of astronomy, with which his name was destined to be inseparably connected. Through the influence of his uncle Lucas Wasselrode, Bishop of Warmia, he was, at the early age of twenty-two, raised to the dignity of Canon of Frauenburg, a town on the coast, near the mouth of the Vistula, and, having completed the obligatory year of residence, he obtained from

the Chapter three years' leave of absence for the purpose of completing in Italy the course of study begun in his native country. Towards the end of 1496 he was enrolled amongst the students at the University of Bologna, where he inscribed his name on the list of the Poles who frequented that famous seat of learning—a circumstance which has been cited as an additional proof that he was not a German. Early in the following year the Ferrarese astronomer, Domenico Maria Novara, had already found in him a zealous assistant in his nightly observations.

The interval between the first arrival of Copernicus in Italy and his final departure from that country, was of eight years—from the end of 1496 to that of 1504. But his sojourn was interrupted by two homeward journeys for the purpose mainly of obtaining renewed leave of absence from the Chapter of Frauenburg. The first was in 1499, after the University of Bologna had conferred upon him the degree of Doctor of Laws. Later in the same year he returned to Bologna, accompanied by his brother Andrew; but finding themselves in extremely necessitous circumstances—probably because the pittance which had been bread for one was starvation for two—the brothers repaired to Rome in the jubilee year 1500. There for about ten months Nicholas taught mathematics amid the plaudits of thronging audiences. Again in 1501 both Nicholas and Andrew Copernicus were in Poland, and this time the Chapter of Frauenburg granted them a more prolonged leave for the purpose of studying at Padua. The permission, we are told, was granted the more readily because Nicholas had promised to devote himself to medicine. Thus when, after three years' further study, he finally returned to his native land, he was a Doctor in two faculties, as well as a competent classical scholar, a rare mathematician, and the astronomer all the world knows of.

The remainder of his life, which extended to the term allotted to man by the Psalmist, was spent in the little town of Frauenburg, his attention being divided between the duties of his ecclesiastical office and the cultivation of astronomical science. He employed a great portion of his time in works of charity and in giving good advice; he visited the sick poor; he projected the construction of a hydraulic machine to distribute water in all the houses of the town; he occupied himself with the best mode of coining money; and he successfully pleaded the cause of his colleagues in a law-suit brought by the Chapter of Frauenburg against the knights of the Teutonic

Order. In the little cathedral town on the banks of the Vistula no passion disturbed the peaceful tranquillity of his existence. An enemy of useless conversation he did not seek for praise nor the clamour of glory; independent without pride, content with his lot and content with himself, he was great in obscurity, and revealing himself only to a small number of chosen disciples, he accomplished a scientific revolution without Europe being aware of the fact during his lifetime.

Copernicus read carefully the explanations which Ptolemy and other ancient astronomers had given of the movements of the sun and planets, but none of their theories satisfied him, because he could not make them agree with what he himself observed. At last, after many years of labour, he came to the conclusion that the real explanation was the one which Aristarchus had given, and which was called the Pythagorean system—namely, that the sun stands still in the centre of our system, and that the earth and other planets revolve round it.

The results of his labours he embodied in a volume which is the foundation of modern astronomy. But he hesitated for a long time to publish the work which has immortalized his name. Persuaded at last by the reiterated solicitations of his friends, especially Cardinal Schomberg and Tidemann Gysius, Bishop of Kulm, he determined, at the age of seventy, to send to the press, at Nuremberg, his "De Revolutionibus Corporum Cœlestium," which had been in preparation for nearly thirty-six years. He directed his pupil Rheticus to revise the proofs, and a few days before his death he had the satisfaction of holding in his failing hands a complete copy of his work.

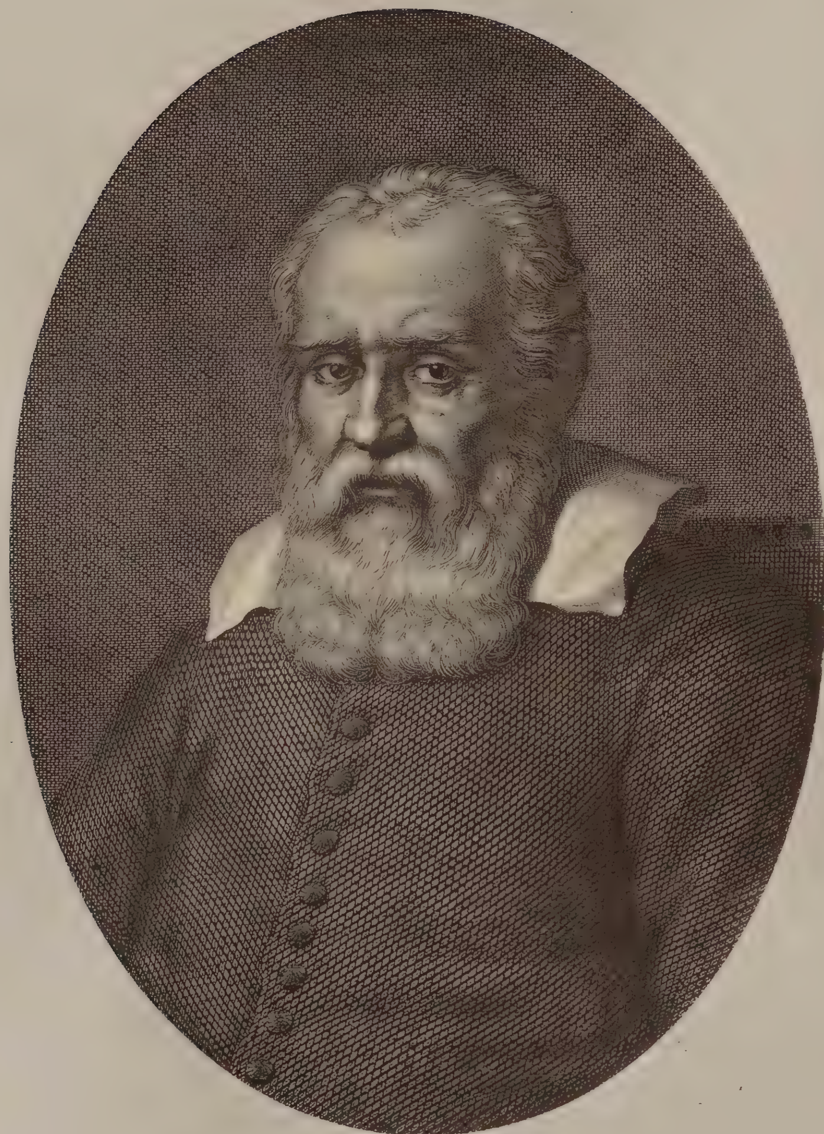
Copernicus came into the world at that period of revival when the human mind seemed suddenly to wake up after a sleep of ages. That sleep, however, had been apparent and not real, for all the great problems then so eagerly canvassed were not new. More than once they had been put forward by bold thinkers whose utterances were soon stifled by the dominant authority, or failed to find an echo among their contemporaries. As a general rule it may be safely maintained that every revolution openly accepted has been previously accepted in men's minds. Thus a long time prior to the discovery of America the probable existence of a fourth part of the world had been spoken of, and Copernicus himself was well aware that he was not the first to make the Earth move round the Sun. But extraordinary

perseverance was required in order to gain a hearing for his theory; and in this respect the recent discovery of the New World was a great help to a revolutionary astronomer. There was now no obstacle to the Earth circulating in space, since it had been demonstrated that it forms, with the ocean, one single globe; that it is not immoderately large, and that there may really exist underneath us inhabitants whose feet are opposed to our own. Yet to no man is granted the power of discovering all truths at once. Copernicus continued to deceive himself, in common with the ancients, in reference to the movements of the planets, and he made a great error in his theory of what he called the "third movement of the Earth." In spite of these mistakes and shortcomings, Copernicus is the father of those men of genius who have created modern astronomical science; and the name of the Canon of Frauenburg will be ever memorable, because, to cite his own stately language, he placed "the light of the world—the orb which governs the planets in their circulation—upon a royal throne, in the midst of the Temple of Nature." Kepler and Newton penetrated much more deeply into the mysteries of the heavenly bodies, but it was Copernicus who gave them the key; and even at the present day, after their immortal labours, the true explanation of the universe is called the Copernican system.

COPERNICUS

CHRONOLOGY OF HIS LIFE

1473	BORN AT THORN, PRUSSIA.		
1497	SETTLED AT BOLOGNA	AGE	24
1500	AT ROME	„	27
1530	"DE REVOLUTIONIBUS ORBIUM CŒLESTIUM" . .	„	57
1543	DIED	„	70



Galileo

GALILEO

1564-1642

THE PIONEER OF SCIENCE IN MODERN TIMES

Among the great men who have contributed to the advance of science there are not many whose lives possess so much interest for the mass of men as that of Galileo. Personalities are the delight of the gossip; truth is the joy of the philosopher. To uncultivated persons a man's "life" means what he outwardly does and what visibly befalls him. To the philosophic and reflective it means what he thinks, what he loves, and learns and teaches. The former hunger for adventures, the latter eagerly watch the growth of a mind. But there are very few lives exclusively of the one kind or the other. "The web of our life is of a mingled yarn." The *great man* is still *a man*, and the scientific interest is closely inwoven with the human. This is the case to an unusual degree with Galileo. He was not only the man of science, but he was one of "the martyrs of science;" and to this fact is clearly owing the strong hold which his name has gained on the imagination and interest of men in general.

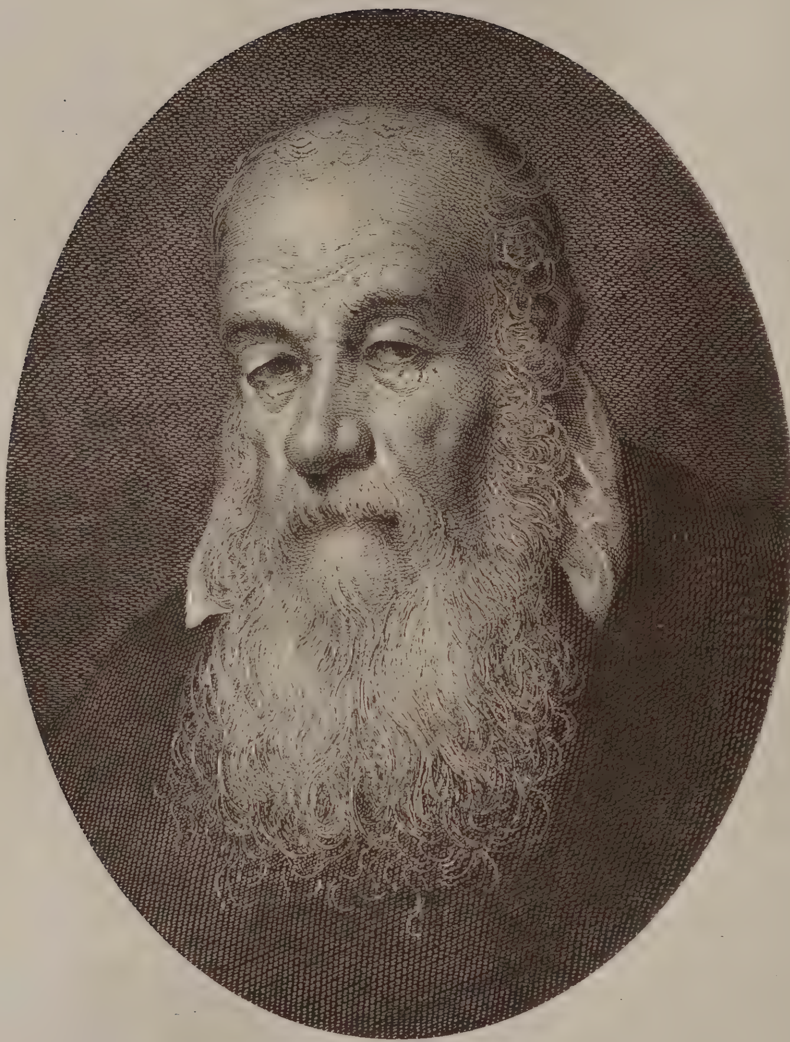
Galileo Galilei was born at Pisa, then a dependency of Florence, February 18, 1564. It was the year of Shakspeare's birth. Bacon was born three years earlier, Campanella four years later, Kepler seven years later. Copernicus had been dead about twenty years. Descartes, Milton, Spinoza, and Locke, were born in the lifetime of Galileo; and Newton was

born the same year that Galileo died. The Galilei family were of noble rank. In boyhood Galileo showed great mechanical inventiveness, and also a fondness for literature. He received his early education at the convent of Vallombrosa, near Florence, was trained in Greek and Latin, and acquired a good style. He tasted of monkish logic, was disgusted, and abandoned it. He had some leaning to a monastic life, and entered upon the novitiate; but his father withdrew him, and wished to make him a physician. At seventeen he entered the University of Pisa to study medicine, and attended the lectures of the famous Andrea Cesalpino. His "gifts" were so various that, like Leonardo, he seemed fit to be and to do anything; might be musician, painter, orator, mathematician, mechanician.

As with Pascal, mathematics were forbidden him, lest they should seduce him from his appointed course. But in 1583, in Pisa cathedral, his thoughts wandering from the service, he watched the swinging of a bronze lamp—it still hangs there—and observed that its oscillations, long or short, were made in equal times. This led him, through experiments, to the discovery of the isochronism of the pendulum. The first use he made of it was to apply it to the pulse, and it was named *pulsilogia*. Long years had to pass before it was applied to clockwork. The same year he accidentally overheard a mathematical lesson given, his native passion was awakened, and Hippocrates and Galen were presently laid aside for Euclid and Archimedes.

In 1586 he left the University without taking a degree. At Florence he lectured on Dante's "Inferno." About the same time he invented and described the hydrostatical balance; and by his work on the centre of gravity in solids acquired the designation of "the Archimedes of his time." His reputation now procured him an introduction to the Grand Duke of Tuscany, and an appointment as lecturer on mathematics at Pisa (1589). During his stay he made experiments in dynamical science, and convinced the Aristotelians against their will of the true law of falling bodies. They could neither refute nor rejoice in him; and his sarcastic style exasperated them. He was hissed at his lectures, and in 1591 he retired to Florence. In the following year he was appointed by the Venetian government to the chair of Mathematics at Padua. This post he filled for eighteen years with immense success and popularity.

To this period (1591–1610) belong a series of inventions and great discoveries: the proportional compasses, the first thermometer, the



Galileo

OLD: AS HE APPEARED BEFORE THE INQUISITION

telescope, and the swift train of startling disclosures made by the last when first directed to the heavens. Galileo was not the inventor of the telescope. Report reached him of such an instrument made in the Netherlands; he seized upon the conception and immediately made one with his own hands. It was his distinction to be the first to apply it to the study of the heavens. He quickly improved upon his first attempt, and afterwards made hundreds of instruments. They were in demand all over Europe. The results of the first few months were astounding. Discovery after discovery gave the lie to the doctrines of the blind guides. First, the moon revealed the mountainous configuration of her surface; next, the Milky Way resolved itself into separate stars; the four moons of Jupiter were seen; the ring of Saturn was seen, but not recognised as such; Venus appeared in a crescent shape; and the Sun-spots were discovered. How is it possible for us, familiar all our lives with these facts, to imagine the confused excitement of delight and consternation which accompanied their first disclosure? The grand scientific result of the whole was the demonstration of the truth of the Copernican theory, which, after making its way for nearly a century so slowly as to seem almost lost, now arose to life, victorious over all gainsayers. Galileo had early accepted this theory, but had abstained from avowing it, more, he says, from fear of derision than of persecution. But he might well dread both. For, had he not heard, in February 1600, how the brave thinker, Giordano Bruno, was burned at Rome? He must have known Bruno's works and learnt something from them; and if the terror entered into him, can we wonder?

It was during his residence at Padua, in 1597, that his friendship with Kepler began, which lasted till Kepler's death in 1632.

Galileo was a courtly man, and he not only named the new-found satellites the "Medicean stars," but named each of the four after some member of the ducal family. In September 1610 he settled at Florence, as philosopher and mathematician to the Grand Duke. In the spring of 1611 he visited Rome, was cordially received, and with his "optic tube" showed the wonders of the heavens to the folk of the papal court.

But it was soon evident that the conclusive demonstration of the Copernican theory was, with the Church, a *casus belli;* and the war began. Galileo had no wish to raise discussion on the relation of Scripture to Science, but once begun he accepted it fiercely. During 1615 there was a suspension of arms; and Galileo was again well received at Rome at the end of the year. The Inquisition interfered; but only to decree the

Copernican theory to be absurd and false. Bellarmine, the leading member of the Holy College, gave Galileo a warning not to hold, teach, or defend the condemned doctrine. He gave him also a certificate that no abjuration was required, no penance imposed. The next sixteen years he spent in scholarly quiet at Florence. Ominous tidings, however, reached him in February 1619, of another philosopher—"atheist," of course—Vanini, burned by the Inquisition at Toulouse.

In 1632 Galileo published his most important work, the "Dialogue on the Systems of the World." This was the final signal for action. Proceedings were taken under the authority of a decree of the Holy Office passed in February 1616, an absolute prohibition of the teaching of the condemned theory, which had not been published nor communicated to Galileo. (The existence of this decree, long doubted, has now been verified beyond question.) The old man, now 70, and broken in health, was cited to Rome, and underwent the agony of a trial with "rigorous examination," but not with the actual torture. His courage failed him, and to save his life he made a lying abjuration. A spectacle too mournful to dwell on! But the truth falls not when her champion turns coward. Henceforward he was the prisoner of the Holy Office, although allowed to return to Florence.

The next year he lost his belóved daughter—she dies, although

> "He loved her most, and thought to set his rest
> On her kind nursery."

In 1636 he became blind. His last years were spent at his country-house at Arcetri; and here, in 1639, Milton visited him. He is mentioned in "Paradise Lost," but no particulars of the interview are given us. What could Milton—he who could unshrinking face a world in arms—what could *he* say of the abjuration? It might be an exquisite delicacy of feeling that kept him silent. Galileo died at Arcetri, January 8, 1642.

The original records of his trial, preserved in the Vatican, were first published *in extenso* in 1867. Of recent works on Galileo the most noteworthy is that by von Gebler, entitled "Galileo Galilei und Römische Curie," which has finally cleared up the story of the trial. An English translation was published in 1879. The first complete edition of Galileo's works appeared at Florence in 1842–56, in 15 vols. 8vo. There is a good English biography of Galileo, by Drinkwater.

GALILEO

CHRONOLOGY OF HIS LIFE

1564	BORN AT PISA.	
1581	ENTERED UNIVERSITY OF PISA	AGE 17
1582	DISCOVERED LAW OF VIBRATION OF PENDULUM	„ 18
1589–92	LECTURER AND PROFESSOR OF MATHEMATICS	„ 25–8
1597	FRIENDSHIP WITH KEPLER COMMENCED	„ 33
1603	INVENTED THERMOMETER	„ 39
1609	CONSTRUCTED TELESCOPE	„ 45
1610	"SIDEREUS NUNCIUS"; DISCOVERED SATELLITES OF JUPITER	„ 46
1611	REMOVED TO FLORENCE; VISITED ROME	„ 47
1615	APPEARED BEFORE THE INQUISITION AT ROME	„ 51
1624	VISITED ROME AGAIN	„ 60
1632	"DIALOGO SOPRA I DUE MASSIMI SISTEMI DEL MONDO"	„ 68
1633	SUMMONED TO ROME, SIGNED ABJURATION	„ 69
1638	"DISCORSO E DEMOSTR. INTORNO ALLE DUE NUOVE SCIENZE"	„ 74
1642	DIED AT ARCETRI	„ 78

GALILEO

PREFACE TO THE DIALOGUES ON THE COPERNICAN SYSTEM.

JUDICIOUS READER,—

THERE was published some years since in Rome a salutiferous Edict that, for the obviating of the dangerous Scandals of the present Age, imposed a seasonable silence upon the Pythagorean Opinion of the mobility of the Earth. There want not such as unadvisedly affirm, that that decree was not the production of a sober scrutiny, but of an ill-formed passion; one may hear some mutter that Consultors altogether ignorant of Astronomical Observations ought not to clip the wings of speculative wits with rash Prohibitions. My zeal cannot keep silence when I hear these inconsiderate complaints. I thought fit, as being thoroughly acquainted with that prudent determination, to appear openly upon the Theatre of the World, as a Witness of the naked Truth. I was at that time in Rome; and had not only the audience but applauds of the most Eminent Prelates of that Court; nor was that Decree published without Previous Notice given me thereof. Therefore it is my resolution in the present case to give Foreign Nations to see, that this point is as well understood in Italy, and particularly in Rome, as Transalpine Diligence can imagine it to be; and collecting together all the proper Speculations that concern the Copernican System to let them know, that the notice of all preceded the censure of the Roman Court; and that there proceed from this Climate not only Doctrines for the health of the Soul, but also ingenious Discoveries for the recreating of the mind.

To this end I have personated the Copernican in this Discourse; proceeding upon a Hypothesis purely Mathematical; striving by all artificial

ways to represent it Superior, not to that of the Immobility of the Earth absolutely, but according as it is mentioned by some that retain no more but the name of Peripatetics, and are content, without going farther, to adore Shadows, not philosophising with requisite caution, but with the sole remembrance of four Principles but badly understood.

We shall treat of three principal heads. First I will endeavour to show that all Experiments that can be made upon the Earth are insufficient means to conclude its Mobility, but are indifferently applicable to the Earth, moveable or immoveable: and I hope that on this occasion we shall discover many observable passages unknown to the Ancients. Secondly, we will examine the Celestial Phenomena that support the Copernican Hypothesis, as if it were to prove absolutely victorious; adding by the way certain new observations, which yet serve only for the Astronomical Facility, not for Natural Necessity. In the third place, I will propose an ingenious Fancy. I remember that I have said many years since that the unknown Problems of the Tide might receive some light, admitting the Earth's Motion. This Position of mine passing from one to another had found charitable Fathers that adopted it for the Issue of their own wit. Now, because no stranger may ever appear that defending himself with our arms, shall charge us with want of caution in so principal an Accident, I have thought good to lay down those probabilities that would render it credible, admitting that the Earth did move. I hope that by these considerations the world will come to know that if other Nations have navigated more than we, we have not studied less than they; and that our returning to assert the Earth's Stability, and to take the contrary only for a mathematical Caprice proceeded not from inadvertency of what others have thought thereof, but (had we no other inducements) from those Reasons that Piety, Religion, the knowledge of the Divine Omnipotency, and a consciousness of the incapacity of man's Understanding dictates unto us.

With all I conceived it very proper to express these conceits by way of Dialogue which, as not being bound up to the rigid observance of Mathematical Laws, gives place also to Digressions that are sometimes no less curious than the principal Argument.

I chanced to be several years since at several times in the Stupendous City of Venice, where I conversed with Signore Giovan Francesco Sagredo, of a Noble extraction, and piercing wit. There came thither from Florence

at the same time Signore Filippo Salviati, whose least glory was the eminence of his blood, and magnificence of his estate; a sublime Wit that fed not more hungrily upon any pleasure than on elevated Speculations. In the company of these two I often discoursed of these matters before a certain Peripatetic Philosopher, who seemed to have no greater obstacle in understanding of the Truth, than the fame he had acquired by Aristotelian Interpretations.

Now seeing that inexorable Death hath deprived Venice and Florence of those two great Lights in the very meridian of their years, I did resolve, as far as my poor ability would permit, to perpetuate their lives to their honour in these leaves, bringing them in as Interlocutors in the present Controversy. Nor shall the Honest Peripatetic want his place, to whom for his excessive affection towards the Commentaries of Simplicius, I thought fit, without mentioning his own name, to leave that of the Author he so much respected. Let those two great souls, ever venerable to my heart, please to accept this public Monument to Posterity, the Considerations I have promised.

There casually happened (as was usual) several discourses at times between these Gentlemen, the which had rather inflamed than satisfied in their wits the thirst they had to be learning; whereupon they took a discreet resolution to meet together for certain days, in which, all other business set aside, they might betake themselves more methodically to contemplate the wonders of God in Heaven, and in the Earth: the place appointed for their meeting being in the Palace of the Noble Sagredo. After the due, but very short compliments, Signore Salviati began in this manner.

Kepler

KEPLER

1571-1630

THE LAWS OF CELESTIAL MOTION

JOHN KEPLER, one of the greatest astronomers of all ages, was a native of Magstatt, near the imperial city of Weil, in the duchy of Würtemberg. His parents were Henry Kepler and Catharine Guldenmann, both of noble, though decayed, families. Henry Kepler at the time of his marriage was a petty officer in the Duke of Würtemberg's service; and a few months after the birth of his eldest son John, in 1571, he joined the army then serving in the Netherlands. His wife followed him, leaving their son, then in his fifth year, at Leonberg, under the care of his grandfather. He was a seven-months child, very weak and sickly; and after recovering with difficulty from a severe attack of small-pox, he was sent to school in 1577. Henry Kepler's limited income was still further reduced on his return into Germany the following year in consequence of the absconding of one of his acquaintances for whom he had incautiously become surety. His circumstances were so much narrowed by this misfortune that he was obliged to sell his house and nearly all that he possessed, and for several years he supported his family by keeping a tavern at Elmendingen. This occasioned great interruption to young Kepler's education; he was taken from school and employed in menial services till his twelfth year, when he was again placed in the school at Elmendingen. In the following year he was again seized with a violent

illness so that his life was almost despaired of. In 1586 he was admitted into the monastic school of Maulbronn, where the cost of his education was defrayed by the Duke of Würtemberg.

The three years following his admission to Maulbronn were marked by periodical returns of several of the disorders which had well nigh proved fatal to him in his childhood. During the time some disagreements arose between his parents, in consequence of which his father quitted his home, and soon after died abroad. After his father's departure his mother also quarrelled with her relations, having, we are informed, been treated "with a degree of barbarity by her husband and brother-in-law that was hardly exceeded even by her own perverseness." Notwithstanding these disadvantages Kepler took his degree of Master at Tübingen—with which university the school of Maulbronn was connected—in 1591, attaining the second place in the annual examination.

Two years afterwards the astronomical lectureship at Grätz in Styria became vacant and was offered to Kepler, who was forced to accept this situation by the authority of his professional tutors. In 1597 he married a beautiful and noble lady, who was a widow for the second time, though only twenty-three years of age. The income he derived from his professorship was very small, and as his wife's fortune turned out much less than he had been led to expect, he was not only annoyed by pecuniary difficulties, but involved in disputes with his wife's relations.

On the outbreak of the religious persecutions in Styria, Kepler, who was an avowed Protestant, judged it prudent to retire into Hungary. He was soon recalled to Grätz by the States of Styria, but the city was still divided into two factions, and Kepler found his situation very uncomfortable.

In 1599 he went to Prague to assist the distinguished astronomer Tycho Brahé in his researches. His position was not, however, improved. "Everything is uncertain here," he wrote to his friends. "Tycho is an ill-tempered man, with whom it is impossible to live." Handsome remuneration had been promised to Kepler, but he experienced much difficulty in procuring payment, and had to extort from Tycho, florin by florin, the means of subsistence. Fortunately for him Tycho died in 1601, and he was soon afterwards appointed principal mathematician to the Emperor Rodolph, with a pension of 1500 florins. He now fixed his residence at Linz. "The pay is good," he writes, "but the exchequer is empty. I spend my time at the door of the Crown Treasurer and in begging." Kepler was consoled for all these mortifications by the free use which he

had from this time of the original observations of Tycho, and the possibility of discovering in them the secret of the planetary movements. In 1611 he lost three children, as well as his wife, who had become first epileptic and then mad.

After the death of Rodolph, his successor, the Emperor Matthias, continued Kepler in the office of Imperial Mathematician, and sent him to the Diet of Ratisbon to assist in the correction of the calendar. The arrears then due to him amounted to 12,000 crowns, and although he travelled in the retinue of the Emperor he was obliged, in order to live, to compose little almanacs containing prognostications Poverty soon afterwards placed him under the necessity of accepting a chair of mathematics at Linz. There he contracted a second marriage with the beautiful Susanna Reuthinger, by whom he had seven children.

His happiness was of brief duration. The priests of Linz and the Protestant pastors of Würtemberg simultaneously brought against him a charge of heresy which he had great trouble in rebutting. In 1615 a letter arrived from Kepler's sister imploring the aid of this great man in favour of their mother, who was accused of witchcraft. The suit lasted more than five years. After having vainly demanded in writing the intervention of the Duke of Würtemberg to stop this extraordinary persecution, Kepler journeyed on horseback from Linz to Stuttgart, in order to try the effect of his personal solicitations. In spite of his high renown, he could only succeed in modifying the sentence pronounced on his mother, who was then seventy-five years of age. The judges decided that the executioner should terrify the old woman by showing to her one by one the instruments of torture, explaining to her at the same time their mode of action and the progressive increase of the pain they inflicted. This terrible explanation was made, but the old woman resisted all threats, and wound up with this declaration : "I will say in the midst of the torments that I am a witch, but it will be a lie all the same." Her courage produced such an effect that she was released. Kepler returned to Linz, but his enemies insulted him to such a degree as the son of a witch that he was obliged to leave Austria.

Previously to this, in 1620, Kepler was visited by Sir Henry Wotton, the English ambassador at Venice, who, finding him oppressed by pecuniary difficulties, urged him to go over to England, where he assured him of a welcome and an honourable reception; but Kepler could not resolve upon the proposed journey, although in his letters he often returned to the consideration of it.

Soon afterwards Albert Wallenstein, Duke of Friedland, a great patron of astrology and one of the most distinguished men of the age, made a most munificent offer to Kepler, who in consequence took up his residence at Sagan, in Silesia. The duke treated him with liberality and distinction, and by his influence with the Duke of Mecklenburg he obtained for him a professorship in the University of Rostock.

In the frequent journeys on horseback which he made between Sagan and Ratisbon to obtain the arrears of his pay from the Emperor, his health gave way, and he died at the age of fifty-nine. He left at his death twenty-two crowns, one coat, two shirts, and no books except fifty-seven copies of his "Ephemerides" and sixteen copies of his "Rodolphine Tables." His body was buried in St. Peter's churchyard at Ratisbon.

This great man published no fewer than thirty-three separate works. His discoveries in optics, general physics, and geometry are numerous ; but his fame rests chiefly on the discovery of three remarkable laws by which the movements of all the planets are explained. The first of "Kepler's Laws," as they are called, is that planets move round the sun in ellipses or ovals, and not in circles ; the second law is that planets describe equal areas about their centre in equal times ; and the third law is that the squares of the periodic times of the planets are proportional to the cubes of their distances. Even if Kepler had never turned his attention to the heavens, his optical labours would, as Sir David Brewster justly points out, have given him a high rank amongst the original inquirers of his age ; but when we consider him also as the discoverer of the three great laws which bear his name we must assign him a rank next to that of Newton. The history of science does not present us with any discoveries more truly original, or which required for their establishment a more acute and vigorous mind. The speculations of his predecessors afforded him no assistance. From the cumbrous machinery adopted by Copernicus, Kepler passed at one step to an elliptical orbit, with the sun in one of its foci ; and from that moment astronomy became a demonstrative science. The splendid discoveries of Newton sprang immediately from those of Kepler, and completed the great chain of truths which constitute the laws of the planetary system. The eccentricity and boldness of Kepler's genius form a striking contrast with the calm intellect and the enduring patience of Newton. The bright spark which the genius of the one elicited was fostered by the sagacity of the other into a steady and enduring flame.

KEPLER

CHRONOLOGY OF HIS LIFE

1571	DATE OF BIRTH.	
1591	M.A. AT TÜBINGEN	AGE 20
1594	LECTURER ON ASTRONOMY AT GRÄTZ	,, 23
1596	"PRODROMUS DISSERTAT. COSMOGRAPH."	,, 25
1601	ASSISTANT TO TYCHO BRAHÉ	,, 30
1602	"DE FUNDAMENTIS ASTROLOGIÆ"	,, 31
1604	"PARALIPOMENA AD VITELLIONEM"	,, 33
1606	"DE STELLÂ NOVÂ"	,, 35
1609	"ASTRONOMIA NOVA"	,, 38
1612	PROF. AT LINZ; MATHEMATICIAN TO EMPEROR	,, 41
1619	"DE COMETIS"; "HARMONICE MUNDI"	,, 48
1627	"TABULÆ RUDOLPHINÆ"	,, 56
1630	DIED AT RATISBON	,, 59

KEPLER

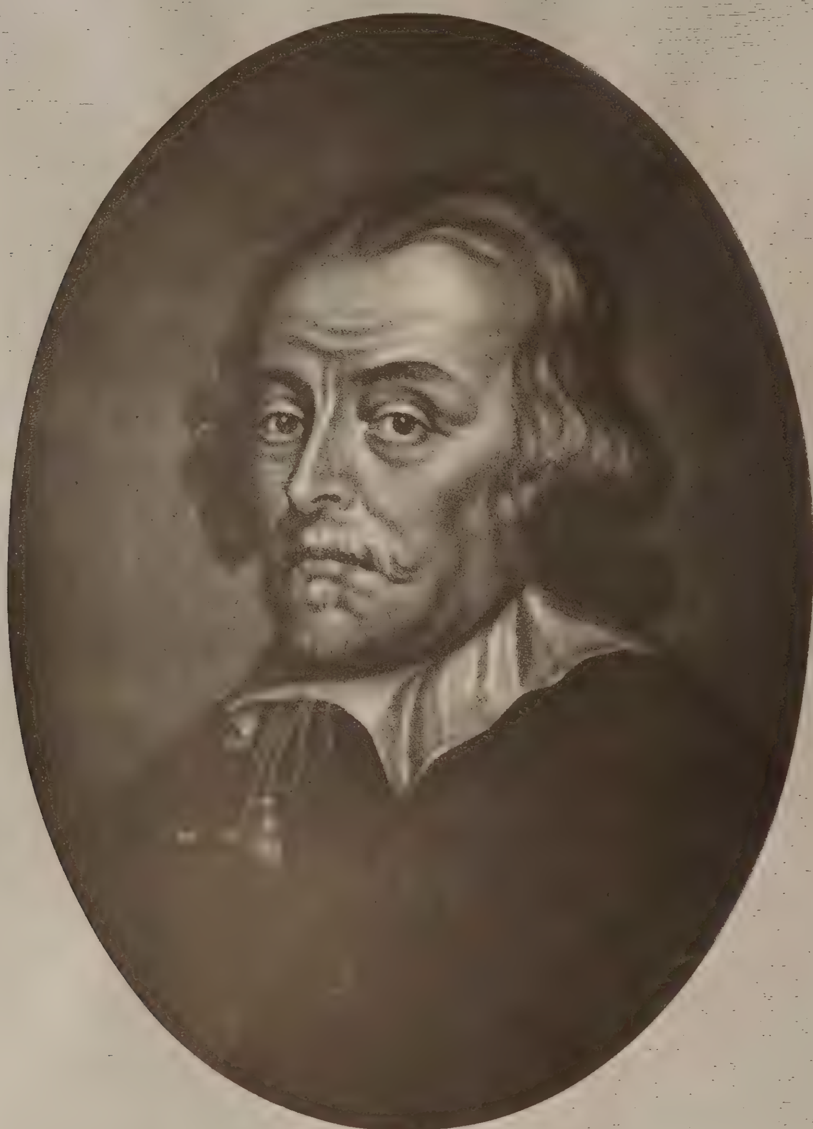
THE LAWS OF MOTION.

Copernicus, by his discovery of the movement of the earth and planets round the sun, laid the foundations of modern astronomy. Galileo strengthened the building by basing the system upon new proofs. But the real form of the earth's orbit and that of the other planets, and the velocity with which they moved in the various portions of those orbits, and their relative distances from the central body remained for Kepler to determine.

Kepler's First Law.—Each planet describes round the sun an orbit of elliptic form, and the centre of the sun always occupies one of the foci.

Kepler's Second Law.—The areas described or passed over by the radii vectores of a planet, round the solar focus, are proportionate to the time taken in describing them.

Kepler's Third Law.—The squares of the times of revolution of the planets round the sun are proportional to the cubes of the major axes.



HARVEY

HARVEY

1578-1657

DISCOVERER OF THE CIRCULATION OF THE BLOOD

William Harvey, the greatest physiologist the world has seen, was a native of Folkestone, in Kent. His father was a yeoman in substantial circumstances, and brought up a large family, nine in number, five of whom became merchants of note and consideration in the city of London. At ten years of age William Harvey was sent to the grammar school at Canterbury, and at sixteen was entered a pensioner of Caius College, Cambridge, where he spent some years in the study of logic and natural philosophy, as preparatory to the study of medicine. He next travelled through France and Germany to the University of Padua, then the most celebrated school of medicine in the world, where he attended with the utmost diligence the lectures of Minadous, Fabrizio d'Acquapendente, and Casserius. From the first he attracted the marked notice of his eminent teachers, who, high as was the estimate they had formed of his abilities and attainments, were nevertheless surprised at the accuracy and extent of the knowledge which he evinced preparatory to his doctor's degree. This was conferred upon him in 1602, and his diploma is couched in terms of extraordinary approbation.

Having returned to England in the course of the same year, he was incorporated Doctor of Medicine at Cambridge; and then going to London, and taking to himself a wife, in his twenty-sixth year, he entered on the practice of his profession. On the recommendation of King James I., backed by that of the President and of several members of the College of Physicians, he was elected physician to St. Bartholomew's Hospital; and afterwards he was appointed Lumleian lecturer on anatomy and surgery in the College of Physicians—an office then held not for a definite period only, but for life. Harvey commenced his lectures in 1616, and is generally supposed to have expounded on this occasion those original and complete views of the circulation of the blood which have rendered his name immortal. It was not, however, until 1628 that he gave his views to the world at large in his celebrated treatise entitled "Exercitatio Anatomica, de Motu Cordis et Sanguinis," having then, as he states in the preface, for nine years and more, gone on demonstrating the subject before his auditory at the College of Physicians, illustrating it by new and additional arguments, and freeing it from the objections raised by the skilful among anatomists. This discovery was of such vast importance to medical science, that when men became satisfied, as they did in the course of a few years, that it could not be contested, several put in a claim for the prize themselves, and many affirmed the discovery to be due to others.

At one period Harvey's professional emoluments must have been very large; but it is sad to relate that the appearance of his admirable "Exercise on the Motion of the Heart and Blood," while it immortalized his name, gave a decided check to his professional prosperity. Aubrey tells us he had "heard him (Harvey) say that after his book on the 'Circulation of the Blood' came out, he fell mightily in his practice; 'twas believed by the vulgar that he was crack-brained, and all the physitians were against him."

About the year 1618 Harvey was chosen one of the physicians extraordinary to the reigning sovereign, James I., and afterwards he became physician in ordinary to Charles I. He always spoke of the latter monarch in terms of unfeigned love and respect; and King Charles, in turn, loved and honoured his physician. It was certainly worthy of the sovereign who appreciated, while he commanded, the talents of a Vandyke and a Rubens, that he also prized and encouraged the less brilliant but not less useful genius of a Harvey.

For a considerable time Harvey followed the fortunes of his royal master. He was with him at the battle of Edgehill, and during the engagement, as we are told by Aubrey, the Prince of Wales and the Duke of York were committed to his care, when "he withdrew with them under a hedge, and tooke out of his pocket a booke and read. But he had not read very long before a bullet of a great gun grazed on the ground neare him, which made him remove his station." Harvey accompanied the King to Oxford after the battle, and was there incorporated Doctor of Medicine. In 1645 he was, by royal mandate, elected warden of Merton College, in place of Nathaniel Brent, who had withdrawn himself from the office, had left the University, and had taken the covenant. This preferment was merited by Harvey, on account not only of his fidelity and services, but of his sufferings in the royal cause, for during the confusion of the times his house in London was plundered of its furniture, and—what was a much heavier loss—of his papers, containing a great number of anatomical observations, particularly with regard to the generation of insects.

He did not long possess the wardenship of Merton College, for upon the surrender of Oxford to the Parliament he left the University and repaired to London. From this time he lived in a retired manner, residing either at Lambeth, or in the house of one of his brothers at Richmond.

In the seventy-first year of his age he was prevailed upon by his intimate friend, Dr. George Ent, to permit the publication of his second great work, "Exercises on the Generation of Animals," which had employed so large a portion of his time and attention. Indeed, no one appears to have possessed in a greater degree that genuine modesty which distinguishes the real philosopher from the superficial pretender to science. His great discovery was not publicly offered to the world till after a nine years' probation among his colleagues at home; and the labours of all the latter part of his life would scarcely have appeared till after his death, had not the importunities of a friend extorted them from him.

Worn down by repeated attacks of gout he died on June 3, 1657, and was buried at Hempstead, in Essex.

"In person," says Aubrey, who knew him well, "Harvey was not tall, but of the lowest stature; round-faced, olivaster (like wainscot) complexion, little eye—round, very black, full of spirit—his hair black as a raven, but quite white twenty years before he died."

The honour of discovering the circulation of the blood has been assigned to others. The claims of Fra Paolo Sarpi to be ranked among discoverers in this line of inquiry have proved on investigation to be of the flimsiest description. Andrea Cesalpino's ideas on the circulation of the blood were far nearer the truth, and, in fact, he had very nearly approached and well-nigh anticipated Harvey. To Cesalpino's theory Harvey added little, but that little was all-important, namely, the demonstration of the true function of the heart. Three centuries have now elapsed since Harvey first saw the light, and two and a half from the "natal day of the circulation" (as he terms the date of the first appearance of his book); but, as a living writer remarks, we have not yet exhausted the consequences of his labours. Although each succeeding generation has contributed its quota of new knowledge to that already accumulated, what they have done has but prepared the path of investigation for those to come. Their task, however, will still be to correct and complete, not to supersede, the work of the great English physiologist. His theory must always be the indispensable sub-structure upon which the science of animal life is founded; and each successive storey added to the edifice, each buttress by which it is strengthened, each pinnacle by which it is embellished, serves to enhance the glory of him who drew his plans so straight and laid his foundations so sure.

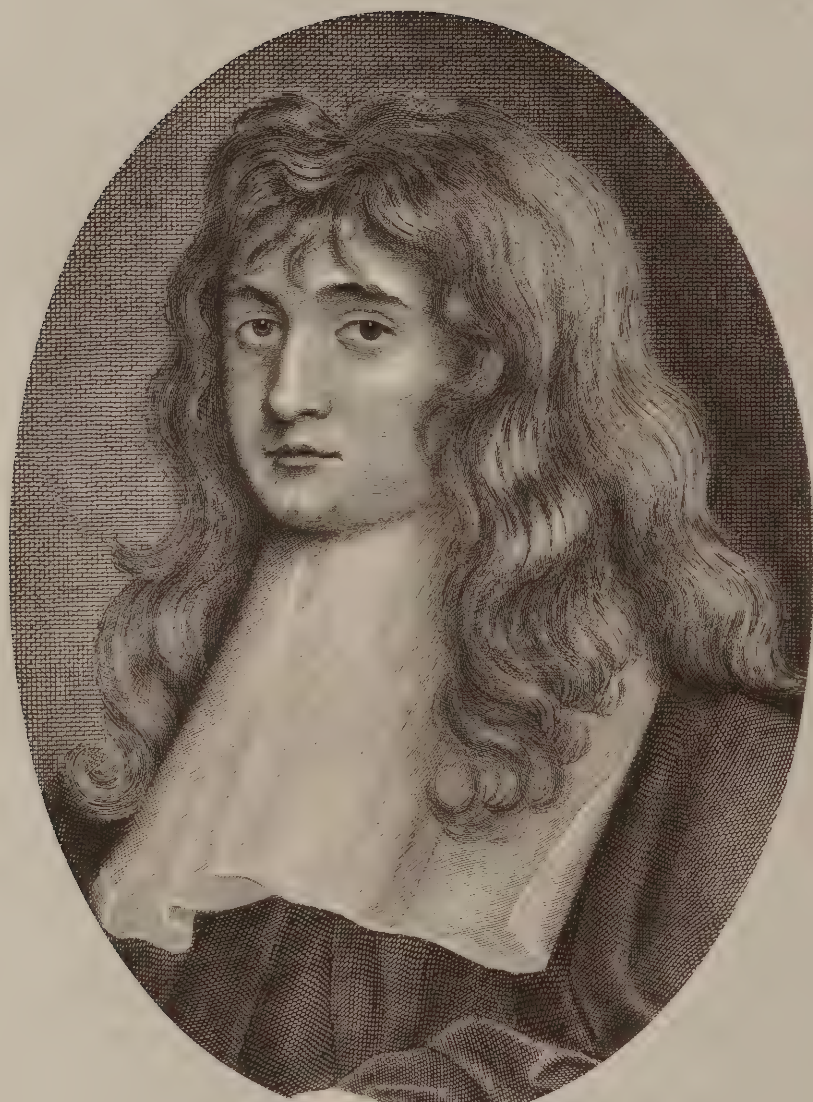
HARVEY

CHRONOLOGY OF HIS LIFE

1578	BORN AT FOLKESTONE.		
1593	ENTERED CAMBRIDGE	AGE	15
1599	STUDIED AT PADUA	,,	21
1602	RETURNED TO ENGLAND ; M.D.	,,	24
1615	LUMLEIAN LECTURER ON ANATOMY AND SURGERY	,,	37
1623	PHYSICIAN TO JAMES I.	,,	45
1628	"EXERCITATIO ANATOMICA DE MOTU CORDIS ET SANGUINIS IN ANIMALIBUS"	,,	50
1632	PHYSICIAN TO CHARLES I.	,,	54
1643	WARDEN OF MERTON COLLEGE	,,	65
1649	"EXERCITATIONES DUÆ ANATOMICÆ DE CIRCULATIONE SANGUINIS," &c.	,,	71
1651	"EXERCITATIONES DE GENERATIONE ANIMALIUM"	,,	73
1657	DIED	,,	79

HARVEY

CONTENTS OF HIS WORK ON THE CIRCULATION



NEWTON

AS A BOY

NEWTON

1642–1727

THE LAW OF GRAVITATION

The little village of Woolsthorpe, in the county of Lincoln, was the birth-place of Newton, who was born in the year that marked the death of Galileo. His father dying previous to his birth, and his mother marrying a second time when he was three years old, he grew up under the charge of his grandmother. At the age of twelve he was sent to the public school at Grantham, and for a time was rather inattentive to his studies, and the last in his class. But one day an incident occurred which effectually roused his dormant faculties. The boy who stood above Newton in the class gave him a severe kick on the way to school, the thought of which rankling in his breast during the morning session, induced him at the close to challenge the boy to a fight in the churchyard, and he had the good fortune to vanquish him; but, though beaten in the churchyard, the boy still stood above him in the class, and Newton determined to supplement the muscular victory by a mental triumph; and though the conflict was longer, it was, like the first, successful, and the position once gained was never lost.

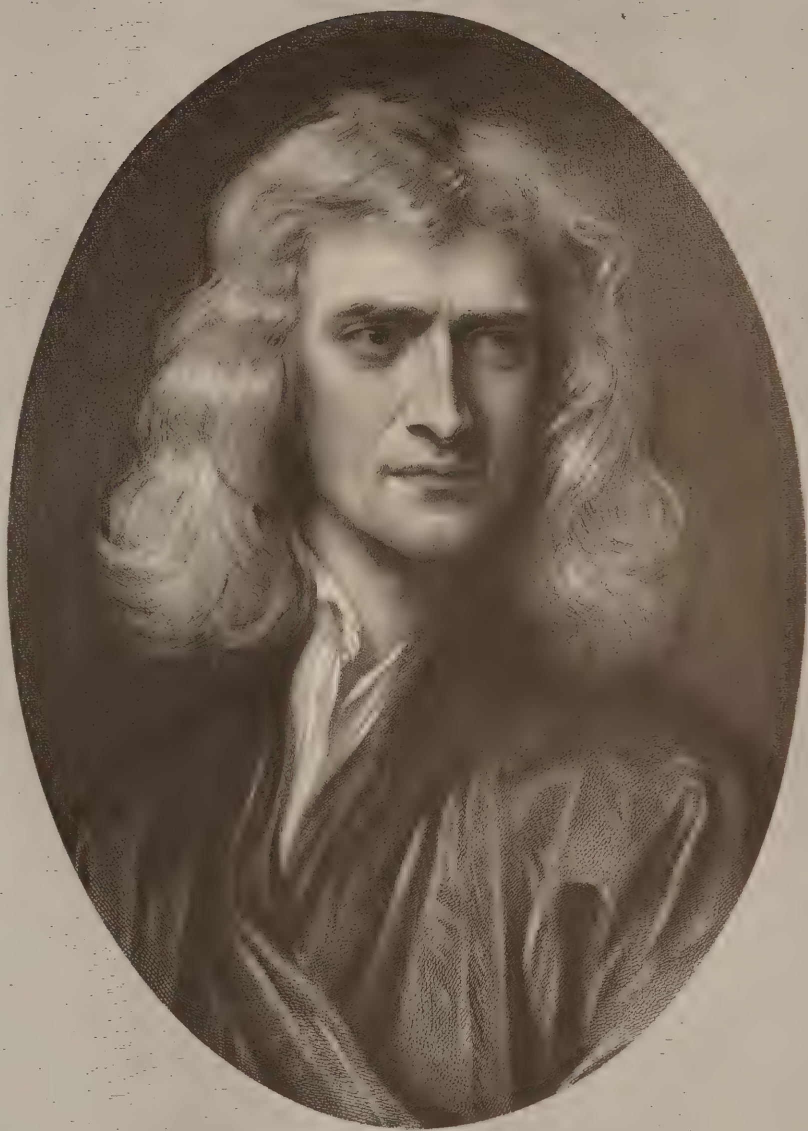
Without doubt Newton's indolence arose from the fact that his health was extremely delicate, and he was already occupied with subjects more

entertaining to him; for he passed all his leisure in constructing little models of known machines, and amusing contrivances for his playmates. He made a water-clock, the index of which was turned by a piece of wood, which rose and fell according to the force of the water. A windmill that was turned by a mouse, and a chair that was propelled by the person occupying it, were others that the "sober, silent, and thinking lad" amused himself by constructing.

After three years at Grantham, his mother, now a second time a widow, returned to Woolsthorpe, and called Isaac from his school to help her in managing the little farm. But his decided tastes for study and meditation prevented him from rendering much service, and, upon the advice of an uncle, it was decided that he should prepare for Cambridge. He was at this time experimenting on the subject of the resistance of fluids—endeavouring to find out the proper form of a body which would experience the least resistance when moving in a fluid. In 1658, on the day of the great storm, (the day that Cromwell died), we find the boy of sixteen determining the force of the gale, by jumping first in the direction of, and then in a direction opposed to, the wind; comparing the length of these jumps with the length of a jump made in a calm day, he computed the violence of the storm.

After a year or more of preparation he entered college, followed the mathematical lectures of Barrow, familiarised himself with the geometry of Descartes and Wallis's "Arithmetic of Infinites"; and, as a result of these studies, put to paper his discovery of the Method of Fluxions. He was also occupied with making researches on the decomposition of light, in which he detected the errors of Descartes, and established his own views on the subject.

In 1665, on account of the plague, the students at Cambridge were dismissed for a time; and it is related that while at home, seated in the garden, the fall of an apple directed his mind to the idea of the law of gravitation, which he afterwards perfected to his lasting renown. "It occurred to him that as the same power by which the apple fell to the ground was not sensibly diminished at the greatest distance from the centre of the earth to which we can reach, neither at the summits of the loftiest spires, nor on the tops of the highest mountains, it might extend to the moon, and retain her in her orbit, in the same manner as it bends into



NEWTON

a curve a stone or a cannon ball, when projected in a straight line from the surface of the earth. If the moon was thus kept in her orbit by gravitation to the earth, or, in other words, its attraction, it was equally probable, he thought, that the planets were kept in their orbits by gravitating towards the sun."

After the re-opening of the University Newton took his degrees, and, in 1669, succeeded Barrow as Professor of Mathematics, and in his lectures exposed his theory of the composition of light and the explanation of the phenomenon of the rainbow. He had at this time constructed his reflecting telescope; but the work which added much to his reputation was his "Universal Arithmetic," probably written for his scholars, and which contains many geometrical problems solved by Algebra.

On the exhibition of his telescope to the King and to the Royal Society, he was elected a member of that body, and, three years later, submitted to them his views on the Inflection and Composition of Light. During the years 1686 and 1687 he presented to the Society his three volumes of the "Principia," which contained the exposition of the law of gravity, founded on Picard's measure of the earth's diameter, and to which we are to believe the fall of the apple contributed so much.

The publication of the "Principia" saw Newton's life work accomplished at the early age of forty-five. It brought him fame and riches, which he lived to enjoy forty years longer. He had already represented Cambridge in Parliament; now he was appointed Warden, then Master of the Mint, and was elected President of the Royal Society. After he was ennobled he became a great favourite at the Court of George I. He had found time, during these years of hard scientific labour, to write a "Commentary on the Apocalypse"; but it does not appear that his researches here were very valuable.

Newton was noted for generosity; and, after his fortune improved, he lived in good style, with six servants, and often gave sumptuous entertainments to his friends and foreigners, and preserved his cheerful, even temper, to the day of his death, which occurred in March 1726.

"We owe to Galileo," says Brewster, "the study of the laws of gravity; those which come into play in the fall of bodies on the surface of our globe. Since the time of this great man it has been discovered that gravity is a force inherent in the matter even of which the terrestrial globe is composed; it is

known that the energy with which it is exercised depends on the distance of the body which is influenced; so that the energy increases when the distance diminishes, and decreases, on the contrary, when the distance augments.

"For example, the flattening of the two poles of the terrestrial globe, or what amounts to the same thing, the swelling of the spheroid towards the equatorial regions, causes the distance from the surface to the centre of the globe to increase continually as the equator is approached. It should therefore follow, that the attraction of the Earth on heavy bodies is exercised with much greater intensity at the poles than at the equator. This fact is abundantly proved by observation.

"The law which regulates this diminution of the force of gravity, when the distance of the heavy body from the centre of the earth increases, is as follows:—

"To understand the law well in its simplicity, let us imagine a heavy body placed on the surface of the earth, and, consequently, distant from the centre of the length of the earth's radius, or, in round numbers, 4000 miles. Let us place it twice, three times, four times . . . ten times further away. The action of gravity on this body will be four times less at 8000 miles; that is to say, at the second position; nine times less at the following position, sixteen times . . . a hundred times less at the consecutive distances; in such a manner that, when the distances increase, following the numbers 1, 2, 3, 4, 5 . . . 10, &c., the force of gravity diminishes in the proportion of the squares of these same numbers, or becomes 1, 4, 9, 16, 25 . . . 100 times less, and so on.

"The force of gravity is measured by the space fallen through during the first second of the body's fall. So that, if experiment shows that a body requires a second to fall from a height of sixteen feet to the surface of the earth, when it is removed to a distance double that of the terrestrial radius, it will not travel more than four feet during the first second of its fall; at a distance sixty times as great as the radius of the earth, it would not fall more than the one-twentieth part of an inch.

"This number gives precisely the measure of the diminution of the energy of terrestrial gravity on a heavy body situate in space at the mean distance of the Moon.

"If, then, the earth exercises its action on bodies situated at whatever distances in space, it ought to act on the Moon, and its action should be

precisely equal to that which we have just calculated. Such is the question which the genius of Newton put to him, and which he solved, when he showed that the Moon, in moving in its circular orbit, falls towards our earth that very quantity in a second. It is this incessant fall, combined with the centrifugal movement, which, if left to itself, would impel the Moon into space, which produces the elliptical movement of our satellite in her orbit. Such is the bold generalization which served as a point of departure to the great geometer whom we have just named.

"He went farther; he penetrated more profoundly into the secrets of the sublime mechanics which rule the celestial bodies. He extended to all the bodies of our Solar System this law, which is sometimes called 'the law of attraction,' but more correctly, 'the law of gravitation.'

"Newton showed, that if the planets move round the Sun, describing elliptical curves, according to the laws the discovery of which is due to Kepler, it is because that they are submitted to a constant force, located, as it were, in the Sun—a force the direction of which is that of a radius vector, or a right line which joins the planet and the common focus. He showed also, that all the circumstances of the movements of the planets are well explained by supposing that the force of gravitation is gravity itself, exercised by the Sun on the planets in the inverse ratio of the squares of their distances.

"Thus the same force which precipitates on to the surface of the earth bodies abandoned to themselves, is that which maintains the Moon in its orbit. It is a force of similar nature, exercised by the preponderant body of the system—the Sun—which also maintains the planets and the comets in their elliptical orbits, and prevents them from losing themselves in space, following the impulse with which they are animated, and thus breaking up our system."

NEWTON

CHRONOLOGY OF HIS LIFE

1642	BORN AT WOOLSTHORPE.		
1660	ENTERED TRINITY COLLEGE	AGE	18
1663	INVENTED "BINOMIAL THEOREM"	,,	21
1665	ESTABLISHED "THEORY OF FLUXIONS"	,,	23
1666	DISCOVERED COMPOSITION OF SOLAR LIGHT . .	,,	24
1668	CONSTRUCTED REFLECTING TELESCOPE	,,	26
1669	PROFESSOR OF MATHEMATICS AT CAMBRIDGE .	,,	27
1672	F.R.S.	,,	30
1676–7	CORRESPONDED WITH LEIBNITZ	,,	34–5
1686	"PRINCIPIA" PRESENTED TO R.S.	,,	44
1687	DEFENDED PRIVILEGES OF CAMBRIDGE BEFORE THE HIGH COMMISSION COURT. . . .	,,	45
1689	MEMBER OF PARLIAMENT	,,	47
1695	WARDEN OF THE MINT; PRES. R.S.	,,	53
1701	M.P. FOR PARLIAMENT	,,	59
1705	KNIGHTED	,,	63
1711	"METHODUS DIFF."	,,	69
1728	DIED AT KENSINGTON.	,,	86

NEWTON

CONTENTS OF HIS WORKS.

The Principia consists of three Books. The *First* and *Second*, which occupy three-fourths of the work, are entitled, *On the Motion of Bodies;* the First treating of their motions in free space, and the Second of their motions in a resisting medium. The *Third* bears the title, *On the System of the World.*

The *First* Book, besides the definition and axioms, or laws of motion, with which it begins, consists of *fourteen* sections, in the first of which the author explains the method of prime and ultimate ratios used in his investigations, and which is similar to the method of fluxions, more fully explained in the Second Book. The other sections treat of centripetal forces and motions in fixed and movable orbits.

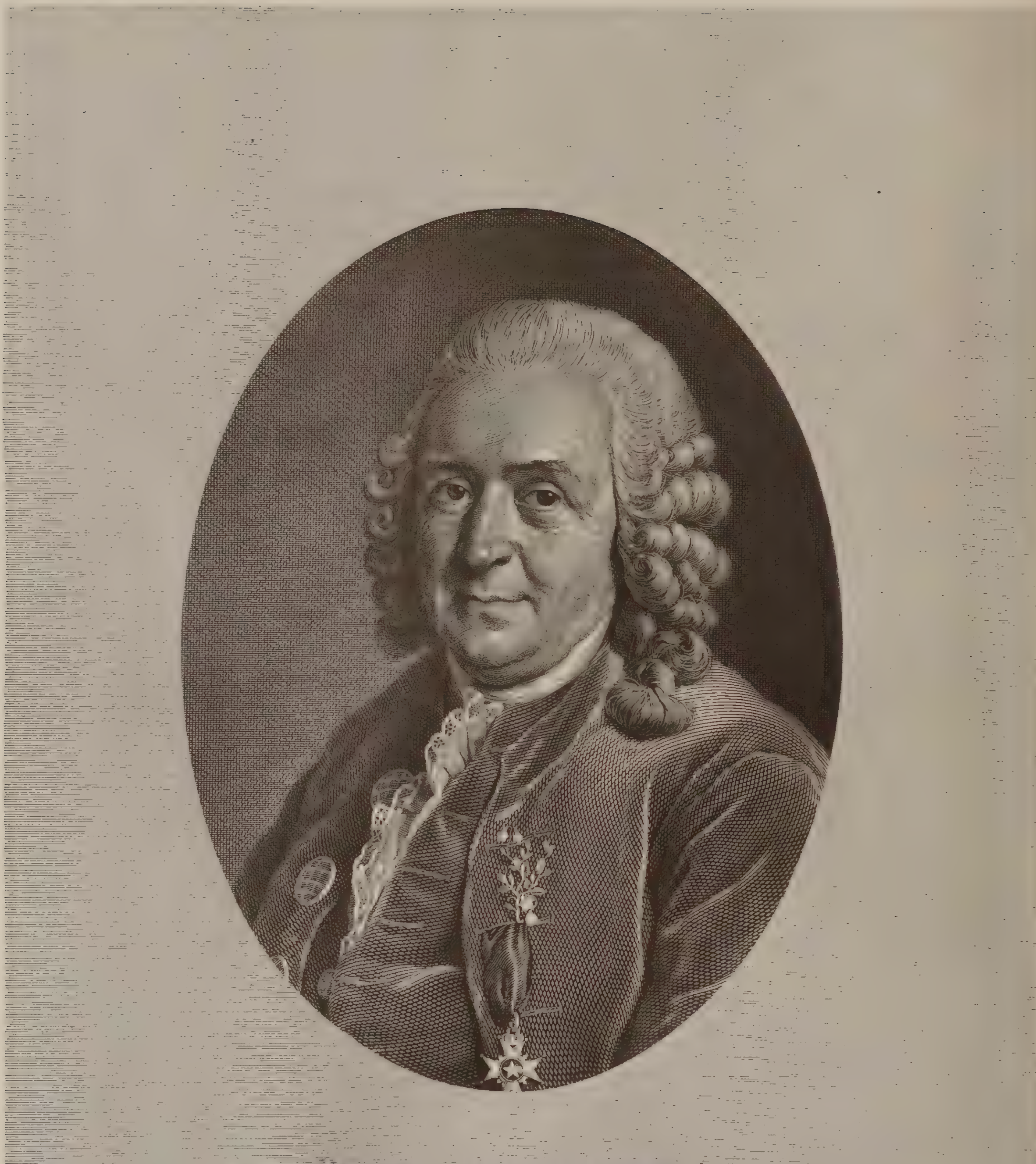
The *Second* Book consists of nine sections, and treats of bodies moving in resisting media, or oscillating as pendulums.

The *Third* Book is introduced by the "Rules of Philosophising." It consists of five sections—on the Causes of the System of the World; on the Quantity of Lunar Errors; on the Quantity of the Tides; on the Precession of the Equinoxes, and on Comets; and it concludes with a general scholium, containing reflections on the constitution of the universe, and on the "Eternal, Infinite, and Perfect Being," by whom it is governed.

The great discovery which characterises the Principia is that of the principle of universal gravitation, *that every particle of matter in the universe is attracted by, or gravitates to every other particle of matter, with a force inversely proportional to the squares of their distances.* In order to establish this principle, Newton begins by considering the curves, which are generated by

the composition of a direct impressed motion with a gravitation or tendency towards a centre; and having demonstrated that in all cases the areas described by the revolving body are proportional to the times of their description, he shows how to find, from the curves described, the law of force. In the case of a circular orbit passing through the centre of tendency, the force or tendency towards the centre will be in every point as the fifth power of the distance. If the orbit is the proportional spiral, the force will be reciprocally as the cube of the distance. If it is an ellipse, the force towards the centre of it will be directly as the distance. If it is any of the conic sections, the centripetal force or tendency towards the focus will, in all points, be reciprocally as the square of the distance from the focus. If the velocity of the impressed motion is of a certain magnitude, the curve described will be a hyperbola; if different to a certain degree, it will be a parabola; and if slower, an ellipse or a circle in one case.

Having established this universal law, Newton was enabled not only to determine the weight which the same body would have at the surface of the sun and the planets, but even to calculate the quantity of matter in the sun and in all the planets that had satellites, and even to determine the density or specific gravity of the matter of which they were composed—results which Adam Smith pronounced to be "above the reach of human reason and experience."



LINNÆUS

LINNÆUS

1707-1778

GREATEST NATURALIST OF MODERN TIMES

The celebrated naturalist, Karl Linnæus, was born at Rooshoolt, a small village in Sweden, where his father was settled as pastor of a Lutheran church. From his infancy Linnæus seems to have been an ardent lover of Nature, and his father, who had some knowledge of Natural Science, taught him the Latin names of all the trees and plants in the vicinity, as soon as he could talk. But his progress in his early studies at the village school was slow, and he often played truant to go in search of flowers; so that he became known by the name of "the little botanist." His father had intended to fit his son for the church, but as years went on he changed his intention upon the advice of the boy's instructors, and arranged to place him at a trade instead. His seventeenth year found him about to be apprenticed to a shoemaker; but, fortunately, a Dr. Rothmann became interested in him, encouraged his love of Nature, and provided for his being received as student at Lund, in the house of Stobæus, the Professor of Natural History there.

After a short stay at Lund, desirous of following the courses of the most celebrated Swedish professors, Linnæus repaired to Upsal in 1728.

His resources were so small that his life was little else than a hard struggle against actual want for months; but it did not prevent his following his studies with zeal, and one day, in the garden of the University, he attracted the attention of Olaus Celsius, Professor of Theology, and a clever naturalist. He became his friend and patron, and employed Linnæus to aid him in his "Hierobotanicon," a description of the plants mentioned in Scripture.

After having studied Burchardt and Vaillant, Linnæus conceived his ingenious and celebrated system of the classification of plants according to their stamens and pistils. In 1731 this plan was published, and the young man of twenty-four, who till then had been only a struggling student, was invited to become deputy-lecturer under the Professor of Botany, and was put in charge of the Botanical Gardens of the University. He now began to sketch out plans for future works: "Classes Plantarum," "Genera Plantarum," "Critica Botanica," and "Bibliotheca Botanica."

His rapid advancement gave rise to such an amount of envy, however, that in 1732 he left Upsal, and accepted a commission from the Academy of Sciences at Stockholm to travel in Lapland, and make researches in the natural sciences. This journey, which comprised about 4000 English miles, was performed on foot, and proves Linnæus to have been full of resolution, courageously braving danger and unremitting toil, for the sake of augmenting the stores of knowledge. This toilsome journey, supplemented by another to Dalecarlia, was badly remunerated, and, on returning to Upsal, Linnæus found his circumstances so very precarious that it appeared necessary to go abroad to try and better his fortunes. In 1735 he visited Denmark, Hamburg, and Holland. At Harderwyk he took the degree of M.D., and at Leyden became acquainted with Boerhaäve, through whose influence he was appointed to take charge of the valuable plants and books belonging to a wealthy Dutch banker, Cliffort. For three years he lived in this delightful house, and brought through the press the works commenced at Upsal. The bounty of Cliffort enabled him, in 1736, to go to England, where he met Dillenius, Professor of Botany at Oxford. Two years later, *en route* to Sweden, he visited Paris, where he was received with great distinction by Bernard Jussieu, and elected corresponding member of the Academy of Sciences.

Arrived at Stockholm, he began the practice of medicine, and became

Professor of Medicine and Botany at Upsal, which latter chair he occupied thirty-seven years. Later he was ennobled, and became physician to the King; was elected a member of all the learned societies of Europe, and became the centre around which revolved all the affairs of Natural History.

The almost universal adoption of his system of botany shows the estimation of the scientific world, and the honours conferred upon him by his Government show how he was regarded at home. The King of Sweden conferred on him the order of the Polar Star, which no man of letters had ever received before, and to which the Queen added many flattering proofs of esteem.

In 1776 Linnæus' health began to fail, and a stroke of apoplexy, followed by paralysis, somewhat impaired his mental faculties. Though he lingered two years, a third shock at last proved too much for his system, and in his seventy-first year he died, universally lamented. The King caused a public medal to be struck, as an expression of the public grief, and erected a monument to his genius beside the one raised to Descartes.

One of the principal titles of Linnæus to glory is his creation of a scientific language, ingenious as it is useful. As a mineralogist he directed the attention of naturalists to the crystal; he made the first classification known, and established the principal modifications. As zoologist he ought to be commended for his ingenious classification of the organs of mastication, digestion, &c., in the animal kingdom. As botanist there is owing to him a complete system, besides the ingenious classification of plants spoken of above. All his scientific labour shows him to have been particularly clever in developing and rendering fruitful the scattered ideas of his predecessors.

The system of Linnæus has not endured without undergoing important modifications; and before his death he amended many of the statements of his previous years; but the uncontested honour remains to him, to have indicated the true method in Natural History. He observed the analogous indications in plants and animals, and they inclined him to attempt something in Zoology. To establish the divisions of the animal kingdom, he made classes of the distinctive characteristics of the parts of the organism destined to the most important functions of life; the brain, heart, lungs, organs of nutrition and locomotion. His zoological labours, without doubt, obtained as great renown as his discoveries in Botany; and he has given,

in his assimilation, a new and startling proof of the extent of his genius. His classification of minerals had only an ephemeral existence; but it was on account of the slow progress that chemical analysis made, this being the essential base of their study.

"When looking over the 'Systema Naturæ' of Linnæus," says one of his biographers, "it is hardly possible, in our day, to realize how great was the influence of that work upon the progress of Zoology. And yet it acted like magic upon the age, and stimulated it to exertions far surpassing anything that had been done in preceding centuries. Such a result must be ascribed partly to the circumstance that he was the first man who ever conceived distinctly the idea of expressing in a definite form what he considered to be the system of Nature; and partly also to the great comprehensiveness, simplicity, and clearness of his method. Discarding in his system everything that could not easily be ascertained, he for the first time divided the animal kingdom into distinct classes, characterised by definite features; he also for the first time introduced orders into the system of Zoology, besides genera and species, which had been vaguely distinguished before. And although he did not even attempt to define the characteristics of these different kinds of groups, it is plain, from his numerous writings, that he considered them all as subdivisions of a successively more limited value, embracing a larger or smaller number of animals, agreeing in more or less comprehensive attributes."

"It is said of Linnæus, that although no man of science ever exercised a greater sway, or had more enthusiastic admirers, yet his merit was not so much that of a discoverer, as of a judicious and strenuous reformer. The knowledge which he displayed, and the value and simplicity of the improvements which he proposed, secured the universal adoption of his suggestions, and crowned him with a success altogether unparalleled in the annals of science."

LINNÆUS

INTRODUCTION TO THE SYSTEM OF NATURE.

THE UNIVERSE comprehends whatever exists; whatever can come to our knowledge by the agency of our senses: the *Stars*, the *Elements*, and this our *Globe.*

The STARS are bodies remote, lucid, revolving in perpetual motion. They shine either by their own proper light, as the *Sun*, and the remote *fixed Stars;* or are *Planets* receiving light from others. Of these the primary planets are solar; *Saturn*, *Jupiter*, *Mars*, the *Earth*, *Venus*, *Mercury*, and *Georgium Sidus:* the secondary are those subservient to and rolling round the primary, as the *Moon* round the earth.

The elements are bodies simple, constituting the atmosphere of, and probably filling the spaces between the stars. *Fire;* lucid, resilient, warm, evolant, vivifying. *Air;* transparent, elastic, dry, encircling, generating. *Water;* diaphanous, fluid, moist, gliding, conceiving. *Earth;* opaque, fixed, cold, quiescent, sterile.

The EARTH is a planetary sphere, turning round its own axis once in twenty-four hours, and round the sun once a year; surrounded by an *atmosphere* of elements and covered by a stupendous crust of *natural bodies*, which are the objects of our studies. It is terraqueous, having the depressed parts covered with waters; the elevated parts gradually dilated into dry and habitable continents. The land is moistened by *vapours*, which rising from the waters, are collected into *clouds;* these are deposited upon the tops of mountains; form small *streams* which unite into *rivulets*, and reunite into those ever-flowing *rivers*, which pervade the thirsty earth, and affording moisture to the productions growing for the support of her living inhabitants, are at last returned into her parent *sea.*

The study of natural history, simple, beautiful and instructive, consists

in the collection, arrangement and exhibition of the various productions of the earth.

These are divided into the three grand kingdoms of nature, whose boundaries meet together in the Zoophytes.

Minerals inhabit the interior parts of the earth in rude and shapeless masses; are generated by salts, mixed together promiscuously and shaped fortuitously. They are bodies *concrete* without life or sensation.

Vegetables clothe the surface with verdure, imbibe nourishment through bibulous roots, breathe by quivering leaves, celebrate their nuptials in a genial atmosphere, and continue their kind by the dispersion of seed within prescribed limits. They are bodies *organized*, and have *life* and not sensation.

Animals adorn the exterior parts of the earth, respire, and generate eggs; are impelled to action by hunger, congeneric affections and pain; and by preying on other animals and vegetables, restrain within proper proportion the numbers of both.

They are bodies *organized*, and have *life*, *sensation*, and the power of locomotion.

Man, the last and best of created works, formed after the image of his Maker, endowed with a portion of intellectual divinity, the governor and subjugator of all other beings, is, by his wisdom alone, able to form just conclusions from such things as present themselves to his senses, which can only consist of bodies merely natural. Hence the first step of wisdom is to know these bodies and to be able, by those marks imprinted on them by nature, to distinguish them from each other, and to affix to every object its proper name.

These are the elements of all science; this is the great alphabet of nature: for if the name be lost the knowledge of the object is lost also; and without these the student will seek in vain for the means to investigate the hidden treasures of nature.

Method, the soul of Science, indicates, that every natural body may by inspection be known by its own peculiar name; and this name points out whatever the industry of man has been able to discover concerning it; so that amidst the greatest apparent confusion the greatest order is visible.

System is conveniently divided into five branches, each subordinate to the other: *class*, *order*, *genus*, *species*, and *variety*, with their names and characters. For he must first know the name who is willing to investigate the object.

The science of nature supposed an exact knowledge of the nomenclature, and a systematic arrangement of all natural bodies. In this arrangement the *classes* and *orders* are arbitrary; the *genera* and *species* are natural. All true knowledge refers to the species, all solid knowledge to the genus.

Of these three grand divisions the *animal* kingdom ranks highest in comparative estimation; next the *vegetable*, and the last and lowest is the *mineral* kingdom.

ANIMALS.

Animals enjoy *sensation* by means of a living organization, animated by a medullary substance; *perception* by *nerves*, and *motion* by the exertion of the will.

They have *members* for the different purposes of life; *organs* for their different senses; and *faculties* or powers for the application of their different perceptions.

They all originate from an *egg*.

Their external and internal structure, their comparative anatomy, habits, instincts, and various relations to each other, are detailed in authors who professedly treat on these subjects.

The natural *division* of animals is into six classes, formed from their internal structure. 1. Mammalia: viviparous; heart with two auricles, two ventricles; blood warm, red. 2. Birds: oviparous; heart with two auricles, two ventricles; blood warm, red. 3. Amphibia: lung voluntary. 4. Fishes: external gills; both classes, heart with one auricle, one ventricle, blood cold, red. 5. Insects, have antennae. 6. Worms, have tentacula; both classes, heart with one auricle, no ventricle; sanies, cold, white.

VEGETABLES.

Nature, by a succession of seeds, with the assistance of the elements, modifies Earths into Vegetables, Vegetables into Animals, and resolves each of them again into Earths in a perennial increasing circle.

Vegetables have life without voluntary motion. They consist of a *Root*, *Trunk*, *Branches*, *Leaves*, and *Flowers*.

A perfect Flower consists of *Calyx*, *Corolla*, *Stamen*, *Pistil*, *Germ*, *Seed*, and *Receptacle*.

Vegetables are distributed into twenty-four Classes, distinguished by the number, situation and proportion of their stamina.

I. Monandria, 1 *stamen* or male in each flower. II. Diandria, 2 distinct *stamina* or males in each flower. III. Triandria, 3 distinct *stamina* in each flower. IV. Tetrandria, 4 distinct *stamina*, all of the same length in each flower. V. Pentandria, 5 distinct *stamina* in each flower. VI. Hexandria, 6 distinct *stamina*, all of the same length in each flower. VII. Heptandria, 7 distinct *stamina* in each flower. VIII. Octandria, 8 distinct *stamina* in each flower. IX. Enneandria, 9 distinct *stamina* in each flower. X. Decandria, 10 distinct *stamina* in each flower. XI. Dodecandria, 12-19 distinct *stamina.* XII. Icosandria, more than 12 *stamina*, fixed in the *calyx* or *petals*, and not on the *receptacle.* XIII. Polyandria, 20-1000 *stamina*, fixed on the *receptacle.* XIV. Didynamia, 4 distinct *stamina*, 2 being longer. XV. Tetradynamia, 6 distinct *stamina*, 4 being longer. XVI. Monadelphia, all the *stamina* united by their filaments into one body. XVII. Diadelphia, *stamina* united by filaments into 1 or 2 sets, *corol* papilonaceous. XVIII. Polydelphia, *stamina* united by filaments into 3 sets. XIX. Syngenesia, 5 *stamina*, united by their *anthers* into a cylinder—*flowers* compound. XX. Gynandria, *stamina* inserted in the pistil. XXI. Monœcia, bearing *stamina* or males, and *pistils* or females on the same plant, but in distinct flowers. XXII. Diœcia, bearing *males* and *females* on separate plants. XXIII. Polygamia, bearing hermaphrodite flowers, and male and female, or both, on same or distinct plants. XXIV. Cryptogamia, fructification concealed.

MINERALS.

The substances of inorganic nature are treated in the last volume of the work in the following order :—

The Water of the ocean, frigid, passive, concipient. Salts, sapid, many-sided, diaphanous. Earths, reducible to dust, dry, dissoluble, fixed. Clay, the earth of marine water. Sand, the earth of rain water. Soil, the earth of vegetables. Calx, the earth of animals. Stones grow from earth, are again resolved and again reproduced. Crystals are stones produced in and from water. Vitriol, the product of alum, intimately allied to metal. Metals are supra decompound, and consist of earth, salt, and sulphur Rocks, appearing like the prominent bones of the earth, of great bulk, solidity and longevity, composed of sand, gravel, &c. Petrefactions, the parents rather than the products of marmoreous mountains, &c., &c.

LAVOISIER

LAVOISIER

1743-1794

FOUNDER OF MODERN CHEMISTRY

Antoine Laurent Lavoisier, whose discoveries laid the foundation of modern chemistry, was a native of Paris. His father, who had acquired a considerable fortune in commercial pursuits, took care to give him an excellent education. He studied with brilliant success at the Collége Mazarin, and carried off a great number of prizes in different classes. When he reached the class of philosophy he evinced so decided an inclination for natural science that he determined to devote the whole of his life to its cultivation; and his father, instead of following the general rule which obliges a young man to adopt a profession or trade, had sufficient courage to confirm him in this resolution. Accordingly, young Lavoisier, on leaving college, began at once to explore the mysteries of mathematics and astronomy in the observatory of the Abbé de la Caille, to practise chemistry in the laboratory of Rouelle, and to follow Bernard de Jussieu in his herbalizings and botanical demonstrations. So intense was his passion for study that he restricted himself to a diet of bread and milk, when he perceived that the want of air and exercise was likely to injure his health; for he

entirely renounced the pleasures of Parisian society in order to devote himself without interruption to his favourite pursuits.

Scarcely had he attained his twentieth year when a prize proposed by the Academy of Sciences gave him an opportunity of making positive researches on an important subject of natural philosophy. The problem was, to discover a more effectual and at the same time a cheaper method of lighting the streets of Paris than was then in vogue. Lavoisier, being desirous to trace the art back, by a series of delicate experiments, to its very first principles, had his room hung with black, and shut himself up in it for six weeks without seeing daylight, in order to render his eyes more sensible to the different degrees of intensity in the light shed by lamps. Such enthusiasm obtained the recognition it deserved, a gold medal being presented to him at a public meeting of the Academy. Previously to this he had accompanied Guettard on several mineralogical expeditions, which gave him new ideas on the structure of the globe—ideas which he developed and then published in a " Memoir on the Layers of Mountains," printed among the proceedings of the Academy. He had also presented to that learned body several essays on special chemical subjects, such as the pretended conversion of water into earth, and the analysis of the plaster of Paris. This latter essay was written with such admirable method and perspicuity, and the experiments were so exactly appropriate to the object in view, as to render it obvious that great discoveries might be expected from the author. Accordingly the Academy hastened to enroll him among their members, and in 1768, at the early age of twenty-five, Lavoisier was elected an associate, on a vacancy being caused by the death of Baron.

The young chemist was not long in perceiving that a fortune might be required in order to carry out the experiments which he had in contemplation. Therefore he decided to sacrifice a portion of his time to pursuits more lucrative than those of science; and a few months after his admission to the Academy he was appointed a Farmer-General, or collector of the public revenues. Some of his colleagues in the Academy were astonished at first that he should have accepted a post of this kind, but they soon learnt that a well-ordered mind, like that of Lavoisier's, only required a very brief space of time every day for the transaction of business, and that there was nothing to prevent him from devoting his principal energies to scientific researches. These he conducted for several hours every morning and

evening, and one day in the week was set entirely apart in order that he might ascertain, by actual experiments, the correctness of the ideas which his studies and meditations had engendered.

In these weekly assemblies, to which learned men of all nations found easy admission, the opinions of the most eminent scientists in Europe were canvassed; passages the most striking and novel, out of foreign writers, were recited and animadverted on; and theories were compared with experiments. Happy hours were passed in these learned interviews, no subject being left uninvestigated that could possibly contribute to the progress of the sciences and the physical amelioration and happiness of man. One of the greatest benefits resulting from these assemblages, the influence of which was soon felt in the Academy itself, and consequently in all the physical and chemical works afterwards published in France, was the agreement established in the methods of reasoning between the natural philosophers and the geometricians. The precision, the severity of style, and the philosophical method of the latter, were insensibly transferred into the minds of the former; the philosophers became disciplined in the tactics of the geometricians, and were gradually moulded into their resemblance. In the assemblage of such a constellation of scientific lights, Lavoisier improved and embellished his own great talents. To the critical examination of these philosophers he submitted the results of his most important experiments, and invited his critical friends to state the most weighty objections that occurred to them; nor did he venture to announce any of his discoveries to the public until they had undergone this ordeal.

Thus Lavoisier became the founder of the French Chemical School, the distinctive character of which was a close and mathematical mode of reasoning in theory, combined with a rigid attention to facts in conducting experiments. The period when that school flourished in its greatest vigour (1780–88) was marked by the most important discoveries, and the most striking alterations were made both in the foundation and superstructure, the doctrine and language of chemistry. Ancient and baseless theories were exploded, the ideal doctrine of Phlogiston vanished before the decisive proofs of experiment, and the new system of Pneumatics was completely established. Although Lavoisier, in this great revolution of science, was assisted by many of the most eminent chemists of the age, yet to him exclusively is due the honour of being the founder of it; his own genius

was his sole conductor, and the talents of his associates were only rendered subservient to the completion of his comprehensive plan, by his own meritorious exertions. For upwards of fifteen years did Lavoisier pursue his chemical experiments and discoveries, without making a single false step; at last, in 1789, he published his "Elements of Chemistry," which presented the science in a form entirely new, and completely distinguished the discoveries and improvements of Lavoisier from those of all former chemists.

In 1794 an order was issued by the Revolutionary Tribunal for the arrest of Lavoisier and twenty-seven other farmers-general, on the paltry charge of having connived at the putting of too much water upon tobacco. Their real offence was the possession of wealth. On hearing that such a decree had been issued, Lavoisier fled and remained for several days concealed in one of the innermost cabinets of the Academy; but finding that this step might be prejudicial to his companions in misfortune, he came forth from his hiding-place and voluntarily delivered himself up. He now became convinced that he should be deprived of his entire property, and resolved to devote himself to the profession of pharmacy, which he had studied in youth. But the release he expected was not in store for him. A decree was passed making the Farmers-General punishable for treason, on the ground of their having made profits from the old government. Under this decree Lavoisier and his companions were sentenced to death by the Revolutionary Tribunal, not, however, without an earnest protest being made by a courageous citizen named Hallé, who read a paper recounting the manifold services rendered to Science and to the State by the great chemist. On hearing his sentence Lavoisier requested a few days' respite, in order to finish some experiments he had been making in prison. Even this poor boon was denied him. The Tribunal rudely answered: "The Republic has no need of learned men." Accordingly, on the 8th of May, 1794, he was guillotined, at the age of 51, along with 123 others. Thus died Lavoisier, one of the brightest stars in the firmament of Science.

LAVOISIER

CHRONOLOGY OF HIS LIFE

1743	BORN AT PARIS.		
1768	ASSOCIATE OF ACADEMY	AGE	25
1769	FARMER-GENERAL	,,	26
1775	"OPUSCULES CHIMIQUES ET PHYSIQUES" . .	,,	32
1776	IMPROVED GUNPOWDER	,,	33
1777	"SUR LA FABRICATION DE SALPÊTRE" . . .	,,	34
1783	DISCOVERED COMPOSITION OF WATER . . .	,,	40
1789	"TRAITÉ ÉLÉMENTAIRE DE CHIMIE" . . .	,,	46
1794	GUILLOTINED AT PARIS	,,	51

LAVOISIER

TABLE OF SIMPLE SUBSTANCES

I. Primary Elements.

Light, Caloric, Oxygen, Azote, Hydrogen.

II. Non-Metallic Substances [Oxydizable and Acidifiable].

Sulphur, Phosphorus, Carbon, the Muriatic Radical, the Fluoric Radical, the Boracic Radical.

III. Metallic Substances [Oxydizable and Acidifiable].

Antimony, Silver, Arsenic, Bismuth, Cobalt, Copper, Tin, Iron, Manganese, Mercury, Nickel, Gold, Platinum, Zinc.

IV. Earthy Substances [Salifiable].

Magnesia, Baryta, Alumina, Silica.

BICHAT

BICHAT

1771-1802

FOUNDER OF GENERAL ANATOMY

GREATEST PHYSICIAN OF MODERN TIMES

Marie Francis Xavier Bichat, the celebrated French anatomist and physiologist, was born in the small village of Thoirette, near Mantua. He was the son of a physician, and received his earliest instruction from his father, and may be said to have been familiar with the Latin language from his earliest years. His classical studies, begun at Mantua, were finished at Lyons, where he commenced the study of medicine in his twentieth year, following the lectures of the celebrated Antoine Petit.

In 1793 the Revolution interrupted his studies at Lyons, and he came to Paris and attended the lectures of the famous surgeon Desault, with the view, at first, of becoming an army surgeon. But the following incident led to a change in this determination. According to a custom in the school, certain pupils were obliged to enlarge their notes of a lecture, and on the day following to read publicly what they had written; thus securing to the class a double hearing of the same subject. On one occasion the student in turn was absent, and Bichat, but lately arrived, promptly offered to take

his place. In his treatment of the subject, which was the fracture of the clavicle, he did not confine himself entirely to the remarks of the professor, but hinted at some new methods of treatment; and this, together with the excellence and brilliancy of its style, caused his abstract to make a lively sensation among both students and professors, and stamped his genius as being of no ordinary type. To this happy incident he owed his friendship with Desault, who immediately discovered his merit. He offered Bichat a home, with the treatment of a son, and destined him to become his successor. He associated him in all his work, gave him a part of his patients to visit, a post at the hospital, and employed him in collecting facts from experiments for an important work. But if Desault exacted much, Bichat performed still more. Notwithstanding the incessant duties of the day, he devoted a large portion of his nights to operations and study upon divers points of the science.

By such profound application he acquired in a short time a fund of knowledge that enabled him to depend on himself alone for means of advancement; and when, at the end of a year, Desault died, Bichat not only was able to continue his investigations with the same success, but undertook to prepare Desault's works for publication, and assumed the support of his widow and son.

After two years of solitary and profound study Bichat opened, in 1797, a school for teaching anatomy, physiology, and surgery. The course of instruction was entirely distinct from that of the Faculty of Paris, and became very popular. Three lectures were often given in one day, and here, as elsewhere, Bichat showed himself a most zealous worker; often preparing the dissections with his own hand before delivering the lecture. His laborious researches in the hospital, the dissecting-room, and the physiological laboratory, were often interrupted by illness brought on by overwork; and it seems extraordinary that he could find time to arrange and perfect his views and researches for publication. In 1800, however, appeared his "Traité des Membranes," in which he laid the foundation for a science of general anatomy.

"He thought only of performing his promises and of enlarging upon the truths of which he had but just given an insight. In a treatise, which he shortly afterwards published, he displayed more fully his doctrines on the membranes, and considered them with respect to their form, organiza-

tion, vital properties, functions, and sympathies. These considerations obliged him to expose, at some length, many of his physiological principles; the latter, however, were in many cases the result of his researches upon the organs themselves. Thus the difference of vital power possessed by the mucous membranes which are subject to the contact of external bodies, and the serous membranes which are withdrawn from such contact, conducted him to the distinction of two kinds of sensibility; he had already distinguished two kinds of contractility. The study of the sympathies in the membrane gave him the happy idea of dividing them according to the vital powers, of which they are only the irregular development, instead of classing them, as is usually done, according to the parts in which they supervene, or from the nature and disposition of the organs in which they are remarked."

"The treatise on the membranes had the greatest success. Immediately regarded as an elementary and classical book, it was cited in almost every work, and given an honourable place in the libraries of the studious.

"About the same time he announced a regular course of physiology, and in a more authentic and universal manner gave the world these principles in his "Physiological Researches on Life and Death." The work is divided into two entirely different parts; the first contains the general exposition of his physiological views; the second is composed of a series of experiments upon the mutual connection of the three principal organs of life—the brain, the heart, and the lungs. These are, indeed, two separate works; the first explains the second, but is not absolutely necessary to it. The opinion which is formed of the one should be entirely independent of that which is formed of the other.

"In his researches on life he exposes, in great detail, the distinguishing characters of the two orders of the functions which serve for the external relations and preservation of the individual. He examines the development of the two lives, and lastly, the manner in which they terminate. This plan, which is filled up with the utmost luxuriance of idea, incessantly presents wherewithal to admire the genius of the author. His theory on sleep will never be forgotten, nor his considerations on what has been named the epigastric centre, nor his table of the vital properties, nor his observations on the progressive manner of natural death."

The same year that his first book appeared he was appointed

physician of Hôtel-Dieu, when in a single winter he dissected six hundred bodies. Devoting himself to the study of therapeutics, he meditated a complete reform in that science, a reform which he would probably have effected had not a sudden death surprised him in the midst of his superhuman toils. Engaged on a large and complete treatise on descriptive anatomy, he carried on his dissections even during the hot days of July, when the heat and unpleasant odours drove all others away, but which could not move him from his studies. Such intense devotion cost him his life; for he was attacked with a fever originating in exposure to the putrescent emanations, and his short but brilliant career was brought to a close in 1802, in the thirty-first year of his age.

Bichat achieved the downfall of the so-called Iatro-mathematical school, which had regarded exclusively the physical phenomena of the living body, exposing on the other hand the fallacy of the then prevalent doctrine that there is in every living body a "vital principle," which governs and directs all its actions. Among others of the important new doctrines propounded in his work "On Life and Death," is the classification of the functions into *organic* and *animal*, which was a great step toward helping to arrange the phenomena of life on a systematic basis. "Altogether," says Carpenter, "Bichat left an impress upon the science of life, the depth of which can scarcely be overrated; and this not so much by the facts which he collected and generalized, as by the method of inquiry which he developed, and by the systematic form which he gave to the study of general anatomy in its relations both to physiology and pathology."

Bichat is one of the few men whose names form epochs in the history of medicine. Medical science, from Hippocrates to Galen, was empiric; from Galen to Harvey, scholastic; from Harvey to Bichat, dogmatic; only since his time has it become scientific. No man has ever penetrated the human organism as he did. All the landmarks of the older anatomists were thrown down—the liver, the heart, the stomach, were no longer regarded as distinct seats of life, but became, under his hand, resolved into the elementary tissues; Physiology was generalized; tissues, not organs, were seen to be the true vital source—the mucous, the vascular, the nervous, the muscular. He set the world to studying the minute structure of the tissues; Physiology became based on Histology, Medicine became based on Pathological Anatomy.

BICHAT

CHRONOLOGY OF HIS LIFE

1771	BORN AT THOIRETTE.		
1793	STUDIED UNDER DESAULT AT PARIS . . .	AGE	22
1797	PROF. ANATOMY	,,	26
1800	"TRAITÉ DES MEMBRANES"; "RECHERCHES SUR LA VIE ET LA MORT"	,,	29
1801	"ANATOMIE GÉNÉRALE," &c.	,,	30
1802	DIED	,,	31

BICHAT

I. LIST OF THE SIMPLE COMPONENT TISSUES OF THE BODY.

The Cellular.	The Fibrous.
The Nervous.	The Fibro-Cartilaginous.
The Arterial.	The Muscular.
The Venous.	The Mucous.
The Exhalent.	The Serous.
The Absorbent.	The Synovial.
The Osseous.	The Glandular.
The Medullary.	The Dermal.
The Cartilaginous.	The Epidermal, &c.

II. TABLE OF THE FUNCTIONS.

[As modified by Ch. Robin.]

VEGETATIVE.

Nutritive.—Digestion, Respiration, Circulation.
Reproductive.—Spermatic, Ovaric.

ANIMAL.

Relational.—Sensation, Locomotion, Expression.
Speculative.—Affections, Intelligence, Activity.

BICHAT

PREFACE TO THE GENERAL ANATOMY.

The general doctrine of this work bears little resemblance to that contained in the prevailing works—physiology and physic. Opposite in its nature to Boerhaave's, it differs not only from that of Stahl, but all others who, like him, have ascribed everything in the living economy to one sole, abstract and ideal principle, whether it be under the name of soul, vital principle, or archaeus.

To analyse with precision the properties of living bodies; to demonstrate that every pathological phenomenon is derived from their increase, diminution, or change; that every therapeutic phenomenon has for its object and principle their restoration to a natural state; to mark distinctly those cases in which such phenomena are found to operate; to ascertain in physiology as in pathology, what proceeds from the one and what from the other; to determine, therefore, in the most accurate and decisive manner which of the natural and morbid phenomena are regulated by those of animal life, and which are produced by those of organic; and lastly, to point out when the animal sensibility and contractility, or where organic sensibility and contractility, sensible or insensible, are called into action; such is the general doctrine of this work. One glance will convince us that it is impossible to define the prodigious influence of vital properties in physiology, without considering them in the points of view I have represented them. It may be said that this manner of investigating them is still theory: to which I answer—the doctrine that demonstrates the laws of gravity, elasticity and affinity, that proves them to be first principles of all the facts observed in physics, is in this case itself a theory. That the relation of properties as causes,

with phenomena as effects, is an axiom in philosophy, chemistry, astronomy, &c., it is in these days scarcely worth while to repeat; and if this work establishes the like axiom in the physiological sciences, it will have attained its end.

There are in Nature two classes of beings, two classes of properties, and two classes of sciences. Beings are organic or inorganic, properties vital or non-vital, sciences, physiological or physical. Animals and vegetables are organic. What are called minerals are inorganic. The vital properties are sensibility and contractility. The non-vital are gravity, affinity, and elasticity. The physiological sciences are composed of animal physiology, vegetable physiology, and physic. The physical sciences are astronomy, natural philosophy, chemistry, &c.

These two classes of sciences belong exclusively to phenomena. Two other classes corresponding to them embrace external and internal forms, and their description. Botany, anatomy, and zoology, constitute the sciences that treat of organic forms; mineralogy, that which treats of inorganic forms. The first will occupy us particularly when we come to examine the connections of living bodies with one another, and with those that are inanimate.

Cuvier

CUVIER

1769-1832

ZOOLOGIST

FOUNDER OF COMPARATIVE ANATOMY

Certain of the world's worthies are born to be initiators, others to raise monuments; those of the first class make epochs, and change the current of human thought or human feeling: such were Socrates and Æschylus. The others are the monument builders, like Aristotle and Shakspeare. While those of the first class change the course of the current, those of the last crystallize it.

There is one of the world's monuments to be found in the Reference room of the British Museum. It is in seventeen volumes, large octavo, full of coloured plates, and bears the following title: "The Animal Kingdom, Distributed According to its Organization, Serving as a Basis for the Natural History of Animals, and an Introduction to Comparative Anatomy."

This is one of the few books that can never grow old. Science as it advances grows more abstract and profound; but the student can scarcely penetrate to the new depths, except by cutting down from the surface. This is a book for a first year's course in Natural History, and it is a book

for the lover of Nature to take up at any time. It is a zoological and anatomical museum entire.

Georges-Léopold-Chrétien-Frédéric-Dagobert Cuvier, the great French naturalist, was born in 1769, at Montbéliard, a town under the dominion of the Duke of Würtemberg. His family were Protestants, who at the time of the Reformation had been driven by persecution from a village in the Jura, which still bears the family name. Cuvier's mother was an accomplished woman, and his father's brother was distinguished for his learning; so that it is not extraordinary that, though being far from robust, he early showed an eager desire to acquire knowledge. At four years he could read fluently, and at six was inquiring into the phenomena of Natural Philosophy. His mother taught him drawing, and helped him with his Latin; so that he was always the first scholar in his classes. As he grew older he became noted for his great memory, skill in drawing, and aptitude for Greek and Latin. At thirteen years of age he began to show that decided taste for Natural History which was to influence his whole life, and now he was never without a volume of Buffon in his pocket. He not only read and re-read it, but copied all the plates in water-colours, or made them out of pasteboard and bits of silk. Besides manifesting an absorbing interest in study, he was quite remarkable for his declamatory powers, and organized among his school fellows a juvenile society, with a code of regulations, and of which he was the president. It met at stated times, when, seated on his bed, after placing his companions round a table, he ordered that some work should be read which treated of natural history, philosophy, or travels. The merits of the book were then discussed, after which the youthful president summed up the whole, and pronounced judgment.

In 1784 he was brought to the notice of Duke Charles of Würtemberg, who took him under his special favour, and sent him, free of expense, to the Carolinian Academy at Stuttgart, which school had a somewhat military character. The pupils were instructed in every branch of knowledge likely to be useful to men destined to govern and direct. Unusual attainments enabled Cuvier to take a place among the foremost, and he had for companions three German boys, who became distinguished men—Schiller, Kielmayer, and Somermering. Cuvier studied hard, gained many prizes, and was one of the five or six out of four hundred pupils, who had the honourable title of Chevalier conferred upon them. He seized every

opportunity for studying natural history, and collected a very considerable herbarium; besides which he drew and coloured an immense number of insects, birds, and plants.

His studies finished, he was promised a place under the administration, but circumstances obliged him to seek employment at once. He found it as tutor in a nobleman's family in Normandy. Here he remained almost eight years; but from his correspondence it is seen that he laid the foundations of his future fame during the very first year of his tutorship, by his researches on Mollusca. He began by accidentally comparing some fossil remains with recent species, and the casual dissection of a *calmar*, a species of cuttle-fish, led him to the study of Mollusca, which were not difficult to obtain, as the sea-shore was near.

All the inferior animals had been included by Linnæus in the class called *Vermes;* but Cuvier, after carefully studying their organization, felt impelled to make a new classification, and arranged them according to their natural affinities; a classification founded on the internal structure of the animal, and not on the form of the shell. He committed his observations to paper, merely for his own use, not realizing the special value of his discovery. But an acquaintance with Abbé Tessier, a refugee of the Revolution, brought these papers to light; and the Abbé, who was a writer of note, enthusiastically transmitted them to Geoffroy Saint-Hilaire, who also saw the importance of such a discovery. A correspondence began, and Cuvier was invited to Paris. "Come quickly," wrote Saint-Hilaire to him; "to play among us the *rôle* of a new Linnæus, another founder of Natural History."

Not till 1794, however, did Cuvier accept the invitation—then, at first became assistant to Mertrud in the Jardin des Plantes, and, at the death of Daubenton, was elected to the chair of Natural History in the College of France. Here he acquired the reputation of being the greatest teacher of his day. He began to publish various papers, chiefly on the structure of the lower animals; and in 1798 produced "Tableau Élémentaire de l'Histoire Naturelle des Animaux;" and later, after vigorous research, gave to the world a great work, the "Fossil Bones of Quadrupeds."

Napoleon was not long in recognizing Cuvier's great administrative ability, and appointed him one of the inspectors-general of education, and he helped to found the royal colleges at Marseilles, Nice, and Bordeaux. One

of the most brilliant productions from the pen of Cuvier is the Report on the Progress of Natural Science from 1789, drawn up at the request of the Emperor. He was also employed in reorganizing the educational institutions of Piedmont, Genoa, and Tuscany, and travelled through Holland, Lower Germany, and Italy, where, besides examining academies, he visited all the museums, making drawings of everything new, and procuring fossil remains. The delicate task of organizing a university at Rome was entrusted to him; and, on his return, Napoleon appointed him Master of Requests, and, just before his abdication, Counsellor of State, which appointment was confirmed by Louis XVIII., who, in addition, created him Baron. In 1818 Cuvier became a member of the French Academy, and, four years later, Grand Master of the Faculties of Protestant Theology, and was instrumental in establishing fifty Protestant *cures* in France.

It might be well to glance at another side of the picture. Cuvier certainly was a most polished courtier, possessing legislative shrewdness, fidelity, and the confidence of those who employed his talents; but he was also, and in as marked a degree, the indefatigable seeker after truth. He may be said to have never lost a moment, and his amusement and relaxation consisted merely in a change of employment. At the beginning of his career he had called his brother to Paris to aid him in making and arranging his collection, and later, when work increased, he employed his pupils to write out, from the notes of his lectures, much of his *Anatomie Comparée*, to which he wrote the introduction, arranged the chapters, and corrected the proofs. As perpetual secretary to the National Institute, he was appointed to write the celebrated *éloges*, in addition to other work; and he might be seen before seven o'clock in the morning arranging work for the various secretaries and amanuenses that he kept employed in the library at the top of his house. At first when he began to publish, as his means were limited, he not only drew but engraved the plates for his works himself. As opportunities presented themselves he had brought out second editions of his works, with modifications and additions, bringing them up to the same point as his investigations and lectures. As he passed the meridian of life he was as unremitting and enterprising in his researches as ever; undisturbed by the political changes which France underwent, he continued the favourite of all parties, a most extraordinary combination of the public functionary and philosopher.

But after almost forty years of research, teaching, and writing, combined with an arduous public life, although his intellectual faculties had never been more brilliant, the bodily frame broke down, and, after a short illness, he paid the great debt of Nature, being in the sixty-third year of his age. Having faithfully served his sovereign, greatly advanced the cause of science, and been ever a friend to the poor and struggling genius, he died universally lamented.

His Works.—His most important works are : "Comparative Anatomy" (1800-1805), "Researches on Fossil Bones," preceded by a "Discourse on the Revolutions of the Globe," and "The Animal Kingdom" (1816-1829). In the first, to the facts gathered by Claude Perrault and Daubenton, he added innumerable observations, and co-ordinated these elements into the form of a doctrine. In the second work he founded a science entirely new, the science of lost species of fossils—in short, Palæontology. In the third he embraced the entire animal creation, applied the principle of the subordination of characters to Zoology, and established the classification which serves to-day for the basis of this science; a classification based upon comparative anatomy. Linnæus had divided the animal kingdom into six classes : quadrupeds, birds, reptiles, fishes, *insects*, and *worms*. Cuvier remarked the extreme difference of creatures confounded in the last two classes of Linnæus, and proposed a new general distribution of the animals with white blood (insects and worms) into the following six classes : molluscs, crustaceans, insects, vermes, echinoderms, and zoophytes.

Until this time Comparative Anatomy was only a collection of facts relative to the structure of animals. Cuvier concluded that anatomy and physiology should form the basis of zoology, and that the most general and constant fact in the organization should determine its grand divisions, and the least general and most variable facts the secondary divisions. He thus established a subordination of character, which ought to be, and alone can be, the principle of a natural method; that is to say, of such a method of arrangement of beings that the place occupied by each of them gives a general idea of its organization, and of the relations which connect it with all others; a method which he regarded as science itself reduced to its most simple expression. Thus, examining the modifications of the organs of circulation, respiration, and sensation throughout the animal kingdom, instead of the six classes of Linnæus, Cuvier established four great types,

vertebrates, molluscs, articulates, and radiates, which he calls embranchments, and divides into classes of nearly equal value with those long established among the vertebrata. This tended very much to raise into importance the inferior animals.

Cuvier's two laws, the law of the subordination of the organs and the law of correlations, with some others, formed part of that science which permitted him methodically to reconstruct a great number of lost species by means of fossil *débris.* "Such was," says M. Flourens, "the vigour and infallibility of this method that Cuvier could recognise an animal by a single bone, or a single facette of a bone."

As a naturalist Cuvier takes a permanent rank among the few great men who have effected great revolutions in the sciences which they have cultivated, and who have left ineffaceable traces of the influence of their discoveries. The whole animal kingdom has assumed under his hands a systematic arrangement, founded on a careful and laborious observation of the analogies of internal structure. He converted the science of Natural History into a science of strict and severe induction, and conferred on it a dignity hitherto unpossessed by it. He reconstructed, as it were, the fossil remains of an antediluvian world, from imperfect fragments. "The 'History of Fossil Bones' must ever remain a classical work to geologists; and the discoveries which it contains are some of the most interesting and extraordinary which observation upon the surface of the globe has ever enabled us to ascertain." To his masterpiece, "The Animal Kingdom," sufficient allusion has been made; the monument builders receive their full share of fame in this world, while the claims of the initiators are often forgotten, often disputed. Many people have never heard of Lamarck; every schoolboy is familiar with the name and work of Cuvier.

CUVIER

CHRONOLOGY OF HIS LIFE

1769	BORN AT MONTBÉLIARD.		
1795	ASST. SUPT. AT JARDIN DES PLANTES, PARIS .	AGE	26
1796	MEMBER OF THE INSTITUTE	,,	27
1798	"TABLEAU ÉLÉMENTAIRE DE L'HISTOIRE NATURELLE," &c.	,,	29
1800	PROF. NAT. PHILOSOPHY, COLLÈGE DE FRANCE .	,,	31
1802	INSPECTOR-GENERAL OF SCHOOLS	,,	33
1812	"RECHERCHES SUR LES OSSEMENTS FOSSILES," &c.	,,	43
1813	ORGANISED UNIVERSITIES AT ROME	,,	44
1814	COUNCILLOR OF STATE	,,	45
1815	CHANCELLOR OF THE UNIVERSITY	,,	46
1816	"LE RÈGNE ANIMAL"	,,	47
1818	VISITED ENGLAND	,,	49
1819	PRESIDENT OF INTERIOR; BARON; "ÉLOGES" .	,,	50
1822	GRAND MASTER OF FACULTIES OF PROT. THEOLOGY	,,	53
1828	"HISTOIRE NATURELLE DES POISSONS"	,,	59
1832	PEER OF FRANCE; DIED	,,	63

HISTORY OF THE CLASSIFICATION OF ANIMALS.

ARISTOTLE.

ANIMALS WITH BLOOD.—Viviparous quadrupeds. Oviparous quadrupeds (*reptiles*). Winged bipeds. Animals with fins. BLOODLESS ANIMALS.—Soft. Encrusted. Shelled. Insected.

LINNÆUS.

MAMMALIA.—Suckling their young. *Primates*, *Bruta*, &c. AVES.—Hatched from the egg. *Accipitres*, *Anseres*, &c. AMPHIBIA.—Reptiles. Serpentes. Nantes. PISCES.—Furnished with gills. Apodes. Jugulares. Thoraci. Abdominales. INSECTA.—Furnished with Antennæ. *Coleoptera*, *Lepidoptera*, *Hymenoptera*, &c. VERMES.—Furnished with tentacles. *Intestina*, *Mollusca*, *Testacea*, *Lithophyta*, *Zoophyta*.

CUVIER.

BRANCH I.—VERTEBRATA.

MAMMALIA.—*Bimana. Quadrumana. Carnivora. Marsupialia. Rodentia. Edentata*, *Pachydermata*, *Ruminantia*, *Cetacea*. BIRDS.—*Accipitres*, *Passeres*, *Scansores*, &c. REPTILIA.—*Chelonia*, *Sauria*, *Ophidia*, *Batrachia*. FISHES.—The Bony series. The Cartilaginous series.

BRANCH II.—MOLLUSCA.

CEPHALOPODA, PTEROPODA, GASTEROPODA, ACEPHALA, BRACHIOPODA, CIRRHOPODA.

Branch III.—Articulata.

Annelida, Crustacea, Arachnida, Insecta.

Branch IV.—Radiata.

Echinoderma, Intestina, Acalephæ, Polypi, Infusoria.

LAMARCK.

Apathetic Animals.—Infusoria, Polypes, Radiaria, Tunicata, Vermes. Sensible Animals.—Insects, Arachnids, Crustaceans, Annelids, Conchiferæ, Mollusks. Intelligent Animals.—Fishes, Reptiles, Birds and Mammalia.

BLAINVILLE.

First Type, Osteozoa (Mammalia). Bearing hair, feathers, scales, fins, &c.

Second Type, Entomozoa (Annulata). With six, eight or ten feet. With a variable number of feet. With no feet.

Third Type, Malacozoa (Mollusks). Cephalopodes, Cephalidians, Acephales.

Fourth Type, Actinozoa (Radiata). Cirrhoderma, Arachnoderma, Zoantharia, Polyparia, Zoophytaria, Spongiaria, Monadaria, &c.

OKEN.

Digestion Animals.—Infusoria, Polypes, Acalephes. Circulation Animals.—Mollusca. Respiration Animals.—Articulata. Carnal Animals.—Fish, Reptiles, Birds. Sensuous Animals.—Mammalia. The first three classes are grouped as Intestine Animals, the last two as Flesh Animals.

EHRENBERG.

Nutrientia.—Warm Blooded, Caring for their Young, Mammalia, Birds. Orphanozoa.—Cold Blooded, not Caring for Young, Reptiles and Fishes. Articulata, Mollusca, Tubulata, Intestine or tube. Racemifera, Intestine forked, Radiata, &c.

OWEN.

MYELENCEPHALA (Vertebrata). HOMOGANGLIATA (Articulata). HETEROGANGLIATA (Mollusca). RADIARIA, ENTOZOA, INFUSORIA.

LEUCKART.

PROTOZOA, COELENTERATA, ECHINODERMATA, VERMES, ARTHROPODA, MOLLUSCA, VERTEBRATA.

VAN BENEDEN.

HYPOCOTYLES.—Yolk Ventral (Vertebrates). EPICOTYLES.—Yolk Dorsal (Articulates). ALLOCOTYLES.—Yolk entirely transformed into embryo (Mollusks and all lower groups).

VON BAER.

PERIPHERIC TYPE (Radiata). *Evolutio Radiata.* MASSIVE TYPE (Mollusca). *Evolutio Contorta.* LONGITUDINAL TYPE (Articulata) *Evolutio gemina.* DOUBLE SYMMETRICAL TYPE (Vertebrata) *Evolutio Bigemina.*

MOQUIN-TANDON.

ISOLATED.—Vertebrata, Mollusca and Protozoa. SEGMENTED.—Articulata, Echinoderma. AGGREGATED.—Zoophyta.

HUXLEY.

PROTOZOA, AGASTRÆA, POLYSTOMATA (Sponges), COELENTERATA, SCOLECIMORPHA, ENTEROCOELA, SCHIZOCOELA (Arthropoda, Annelida, Mollusca, Polyzoa). EPICOELA.—Vertebrata, Amphioxus, Tunicata. Vertebrates divided into *Ichthyopseida* (Fishes and Amphibia), *Sauropseida* (Reptiles and Birds), and *Mammalia.*

APPENDIX TO VOLUME VI.

SOURCES OF THE PORTRAITS

HIPPOCRATES.

Antique bust in the Louvre. Vauthier del. Mecon sculpt. Many busts of Hippocrates exist, all of which correspond. The likeness is well known.

GALEN.

Modern line engraving from the Roman bust in the College of Physicians in London. The head is characteristic, the features strongly marked.

ARCHIMEDES.

From antique bas-relief—Archimedis Effigies marmorea in veteri anaglypho Romæ affervato.

COPERNICUS.

Gravé d'après un tableau du Cabinet de M. de la Lande des Acad. Rl. des Sciences par N. Dandeleau.

KEPLER.

From a painting in the Gallery at Munich. Has been several times engraved. It differs considerably from the Kraenner picture at Ratisbon, but is the one generally accepted.

GALILEO.

Passignani dipinse, Tommaso Minardi disegno, Pietro Bettellini incise. Fine Line Engraving, Didot Coll.

GALILEO, OLD.

Jac. Bassan pinxit. Dom. Cunego sculpsit Romæ 1769. Londini apud Gulielmum Beckfort.

HARVEY.

From the great painting by Vandyke. There is a portrait by Jansen in the College of Physicians, another by Van Reyn, belonging to the Royal Society, another in the National Gallery. The last is very poor.

NEWTON.

From the picture by Kneller, 1689, now at Cambridge. A fine modern stipple, copyrighted by Graves, who has kindly permitted it to appear in this work.

NEWTON AT 16.

Boy with long hair and student's surplice, holding a globe. Published as Newton, but of questionable authenticity.

LINNÆUS.

Fine line engraving by Bervic, Roslin Eques. pinx. Drugulin Coll.

LAVOISIER.

From a miniature; the only portrait current, and repeated in the new editions of his works. There is a stipple engraving bearing his name, which represents a man much younger, and is of doubtful authenticity.

BICHAT.

P. Sudra del. All Bichat's pictures correspond. The features are strongly marked, the forehead finely developed. The appearance is of a man rather older than 31, at which age Bichat died.

CUVIER.

Line engraving, English, 1840. From the painting made in England by W. H. Pickersgill. Inscribed to Prince Albert.